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EDWARD HYATT, State Engineer

Bulletin No. 52

SALINAS BASIN INVESTIGATION

1946

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SECOND MONDAY IN EVERY MONTH

August 27, 1946

H. F. COZZENS— COUNTY SURVEYOR . . . SALINAS, BOX 419
EMMET G. MCMENAMIN— COUNTY CLERK . . . . SALINAS, BOX 811

Mr. Edward Hyatt
State Engineer
Division of Water Resources
Department of Public Works
Sacramento, California

Dear Mr. Hyatt:

Reference is made to the report on the Salinas Basin Investigation which has been carried on under joint agreement between the State Department of Water Resources and the County of Monterey for the past eighteen months.

The undersigned have both been in close touch with the work as carried on by Mr. Russel Simpson of your staff, and on Friday, August 16th, Mr. Zander and Mr. Simpson met with the Water Conservation and Flood Control Committee of Monterey County, and discussed the matters covered by the report.

It was the opinion of the said committee that the report adequately covers conditions in the basin and presents conclusions in which the committee concurs, and which will form the basis of the ultimate design of a plan for the correction of the conditions existing in the basin.

Yours very truly,

Chas. L. Pioda.

Chas. L. Pioda, Chairman
Salinas Valley Flood Control and
Water Conservation Committee of
Monterey County.

H. F. Cozzens

H. F. Cozzens, Secretary.

ACKNOWLEDGMENTS

The Flood Control and Water Conservation Committee of the County of Monterey aided the investigation in an advisory capacity. Special mention is made of the close and helpful cooperation of Mr. Charles L. Pioda, Chairman of the Committee, who contributed to the report an historical account of the development of water utilization in the Salinas Basin.

Acknowledgment is made of the valuable assistance and technical advice given in the conduct of the investigation by Mr. Howard F. Cozzens, in charge of the Engineering Department of the County of Monterey and member of the California Water Resources Board. The records collected under his supervision by the county on water levels at wells in the Salinas Basin from 1933 to 1944 have been included in the basic data submitted in Bulletin 52A.

Mr. A. A. Tavernetti, Monterey County Farm Advisor, gave valuable assistance and cooperation during the course of the investigation. He made available the information on irrigation practices in the Salinas Basin collected by his office and by the University of California Extension Service under the direction of Dr. F. J. Veihmeyer. All water samples collected during the investigation were submitted through the Monterey County Farm Advisor to the Division of Plant Nutrition, Agricultural Experiment Station, University of California College of Agriculture for analysis by Mr. J. C. Martin, Associate Chemist. Comments by Mr. Martin on the qualities of water in the basin were especially helpful.

As a concurrent study in cooperation with this investigation, the Division of Irrigation, Soil Conservation Service, United States Department of Agriculture, Mr. W. W. McLaughlin, Chief of Division, (retired) and Mr. George D. Clyde, his successor, made a survey of irrigation practices and determination of consumptive uses of water in the Salinas Basin. Under the direction of Mr. A. T. Mitchelson, Senior Irrigation Engineer, Messrs. Paul A. Ewing, Senior Irrigation Economist, and Harry F. Blaney, Senior Irrigation Engineer, prepared a report on "Irrigation Practices and Consumptive Uses of Water in the Salinas Basin".

The field work on the survey of irrigation practices in the Salinas Basin was done by Messrs. Lew E. Hanks, S. Burkett Johnson, Clinton W. Renny, and C. Warren Hink under the direction of Mr. Clyde Seibert of the Watsonville branch office of the Soil Conservation Service, United States Department of Agriculture. Information on soils in the basin was submitted by Messrs. Seibert and Johnson.

CHAPTER I

INTRODUCTION

The Board of Supervisors and the Flood Control and Water Conservation Committee of the County of Monterey became concerned in April 1944, over the intrusion of saline water in the ground water supply utilized for irrigation, domestic and industrial purposes in the lower reaches of the Salinas Basin near Monterey Bay. The entire agricultural and urban development in the basin depends on an adequate supply of ground water of good quality.

There had been some abandonment of wells in the Salinas Basin near the bay shore due to excessive salinity as early as 1938. Accelerated encroachment of the contamination occurred in 1943, and the matter was brought to public attention in 1944. The County of Monterey and the Department of Public Works, State of California, executed a contract on July 10, 1944, providing for maintenance in cooperation an investigation of the water resources of the Salinas Valley in Monterey County and conditions relative thereto which obtain in the valley or affect the water supplies available therefor. It further provides that the Department shall prepare a report based on the investigation setting forth the physical facts pertinent to water supply and to salt water intrusion, and if possible, incorporate findings as to a method or methods of solving the problems involved.

Field work by the Division of Water Resources on the Salinas Basin Investigation was begun on July 17, 1944. Collection of data for this report was interrupted in December, 1945, and resumed for general measurement of water levels prevailing at wells in March, 1946. The work accomplished was financed as follows:

State of California (Division of Water Resources)	$13,700
County of Monterey	13,700
Total	$27,400

Development of Water Utilization in Salinas Basin

Mr. Charles L. Pioda, Chairman of the Flood Control and Water Conservation Committee of Monterey County, an agency of the board of supervisors, has been, during the past half century, intimately associated with the development of the utilization of the water resources in the Salinas Basin. Mr. Pioda, who is an authority on this subject, has submitted the following historical account:

"In reviewing the agricultural development of the Salinas Valley, particularly the phenomenal records of production and returns for the recent war years, it is difficult to understand why the pioneer cartographers of California

designated it on their maps as the 'Salinas Desert' unless we realize that the factors that have made the transformation possible have been water and irrigation.

"Water first for the Missions, when the Padres with their Indian neophytes and crude tools led it through hand made ditches from nearby streams, was used to irrigate the fields surrounding those of San Antonio (1771) and Soledad (1791). They produced fresh vegetables, fruit, and wine and had reasonable assurance of cereal crops even in dry years.

"The vagaries of California's rainfall were as unpredictable and extreme then as now. Detailed studies, made by H. B. Lynch, Engineer of the Metropolitan Water District of Southern California, of all available information obtainable concerning the rainfall and climate of Southern California from 1769 on, convinced him of the existence of cycles of dry years eclipsing in length and intensity any that have occurred since actual rainfall records have been kept. The same conclusion was reached by Mr. C. E. Grunsky, C. E., who made a study of water conditions in the Southern San Joaquin Valley and the Tulare Lake Basin after the drought of 1896.

"No doubt such a dry cycle made it necessary to resort to irrigation to provide sufficient food for the hungry Indians that would gravitate to the Missions at such times. Secularization of the California Missions occurred in 1833 and abandonment of all irrigation followed.

"The census of 1850 reported the total California population as 92,597 and that of Monterey County as 1872. This was after the State's population had been increased and Monterey County's reduced as a result of the discovery of gold. The population of Monterey City was reported as 1,092, thus leaving only 780 in the remainder of the County, which at that time included all of the present San Benito County.

"The agricultural population of 780 persons was scattered over the County on land grants that had been made by the Mexican Governor. There were 65 grants, including 648,730 acres in Monterey County and 16 grants, covering 233,046 acres in San Benito County, which were eventually patented by the Federal land office. These grants covered practically all of the valley areas. Land had little value and cattle ranching, the chief enterprise, required relatively large areas. The result was a very sparse settlement.

"Cultivated crops were very limited and methods of tillage primitive. In the gold rush days even such crops as grew were left unharvested because of lack of labor. In 1850 beef cattle sold in San Francisco at $20 to $30 per head.

"The period from 1849 to 1858 was a prosperous one for the ranchers, but in 1859 a decline in their fortunes began, principally because of the competition of better quality beef from other nearby states. The dry seasons of 1862-63 and 1863-64 almost put the original cattle raisers out of business. Streams dried up, feed was short or non-existent, stock died by the thousands or were killed for their hides and tallow, and the best land in the vicinity of Salinas was offered for sale at 50 cents per acre.

"No actual records of precipitation in Monterey County exist for this period. At San Francisco 13.74 inches of rain fell during the winter of 1862-63 and 10.08 during the following winter as compared with a 72 year mean of 22.32 inches. The precipitation at this station for the season of 1850-51 was only 7.42 inches, the shortest of record, but very little has been written about this earlier drought, while the latter has received much prominence in connection with the shift from cattle raising to grain farming. However this actually only served to precipitate a change from a type of agriculture which was becoming unprofitable, to one which was developing possibilities of favorable returns to an increasing number of people. Thus the change could not have been long delayed had the dry years not occurred.

"The exact year when grain was first grown commercially in Monterey County has not been determined, but one of the earliest attempts was by J. B. Hill, who grew 95 acres of barley near Salinas. The returns were such that in 1854 Mr. Hill had 'fenced in 400 acres of plowed land and was making preparations to enclose as many more'. This fencing was necessary to prevent the trespassing of cattle and the expense was prohibitive for the isolated farmer. In 1867 the County Recorder reported that 7,000 acres of land had been enclosed in two years and that 11,000 acres had been improved and put under cultivation.

"The Eleventh Census, the first to take irrigation into consideration, summarizes the status in Monterey County in 1890 as follows:

> 'Irrigation where practiced is conducted on a small scale, the water of springs and rivulets being utilized by individuals having land conveniently situated. On the low ground near the mouth of the Salinas River there were reported to be 60 flowing wells upon farms in 1890, most of them being not far from Castroville. They range in depth from 60 to 189 feet, the average being 136 feet, and they discharge only about 3 gallons per minute. They are reported to fluctuate with the season, many of them ceasing to flow in summer, and in winter barely discharging at the surface of the ground. At Salinas about 10 miles from the coast, most of the deep wells are pumped by windmills.'

"Diversion of water from the Salinas River for irrigation was the first phase of irrigation to assume considerable importance in the American period.

Two claims for small amounts of water were filed in 1877; the first large claim was that of Mr. Brandenstein for 50,000 miner's inches, filed in 1882. The use which was made under this later claim was described in 1890 as follows:

> 'The Canal - takes water from Salinas River in the Southern part of the County ....It is built on the east side of the river for a distance of 6 miles. The average width is 10 feet and the cost was $25,000. The canal, owned by a corporation, was begun in 1884 and first used about 1888. The principal crop irrigated at present is alfalfa. The water supply is fairly good, although the river is dry at times, the water sinking into the bed of the stream.'

"Seventy claims to water from the Salinas River and its tributaries were filed prior to 1901. Only a fraction of them were consummated by the actual use of water. The important ones actually built were one from the San Lorenzo Creek near King City, - two from the Salinas River, one at King City and one at Gonzales, and three from the Arroyo Seco. One, the original Arroyo Seco canal, is still in use at Greenfield, the others had varying and unsatisfactory periods of use and have long since been abandoned.

"The torrential nature of the streams from which water was diverted by these canals, particularly the Salinas, made it extremely difficult to operate and maintain headgates during flood periods, while the small flow of water after the winter's flood subsided made them inadequate for summer irrigation.

"The second important phase of irrigation development was that of pumping directly from the river. In 1897 the Spreckels Sugar Company built steam powered pumping plants to supply its ranches near King City and Soledad with water from the Salinas River. In later years a number of other large steam plants were installed along the river as far north as Salinas. This method of pumping from the river was subject to the same seasonal limitations as was gravity irrigation.

"The third phase, of vastly greater importance than preceding attempts at irrigation, was entered when large scale use began to be made of the water in the underlying gravels of the Salinas Valley. While in the early days of grain farming, limited use had been made of the wells heretofore mentioned for irrigation by installing centrifugal pumps operated by steam threshing engines to raise the water, it was not until the building of the Spreckels factory, near Salinas, in 1897 that the capacity of the underground gravel was demonstrated. In that year in order to obtain satisfactory water for its operations, the Spreckels Sugar Company dug six wells four feet in diameter and 190 feet deep and connected them to central centrifugal pumps with a combined capacity of 5,500 gallons per minute. In addition about 10,000 gallons per minute of water was pumped from the surface flow of water in the Salinas River. All surplus water was used to irrigate adjacent

land largely owned by the Spreckels Sugar Company.

"In 1904 at the King City Ranch of the Spreckels Sugar Company, a similar installation was made of six 20-inch wells 70 feet deep and one of the pumps previously pumping from the river was connected with them. This pump had a capacity of about 6,000 gallons per minute and about 400 acres of alfalfa were irrigated therefrom.

"Driven by the necessity of growing the greater part of the beets for the operation of its factory, the Spreckels Sugar Company arranged to lease a number of large ranches, install pumping plants, and prepare them for irrigation. By 1919 there were 11 such pumping plants in operation with a combined capacity of 80,000 gallons per minute, not including the factory plants.

"By 1915 it was found that the fall flow or water in the Salinas River was insufficient to supply the needs of the factory and an additional installation of wells with 8,000 gallons per minute pumping capacity had to be made. By 1919 a further increase in the supply from wells was required and by 1924 when deep well pumps came into general use, resort was had to that type of pump to provide the necessery supply of water. Finally all old installations had to be abandoned and the full supply needed obtained from new wells and deep well pumps.

"There have been three important steps in the development of the existing pumping situation. First was the extension of electric power lines in 1911 to King City, thus making power available throughout the area.

"Second was the perfection of a reasonably efficient motor driven deep well pump, which could be installed in a single well and operated with a minimum of attention.

"Third was the introduction of vegetable growing in the Salinas Valley on a broad scale in 1924, which gave impetus to the extensive agricultural improvement of the area.

"The financial success that followed this pioneer work caused rapid development of land suitable for vegetable growing. Large pumping plants were abandoned and individual wells and pumps provided in their stead. This development has been continued during the passing years until at the present time little first class land remains undeveloped.

Pumping From Wells and Total Irrigation in Salinas Valley
Monterey County 1889 - 1929

Year	Pumped Wells		Farms Irrigated	Total Acreage Irrigated
	Number	Capacity Gal. per Min.		
1889	*		21	891
1899	*		88	6,675
1909	102	196,235	258	15,056
1919	606	407,310	451	47,336
1929	1,176	1,012,242	803	80,981

U. S. Department of Commerce - Bureau of Census - Reports of Agriculture 1890-1930
*No Report

"In the report on the study of the water conservation problems of the Valley made by the State Department of Public Works, Division of Water Resources in 1931 and 1932 (financed jointly by the State of California and the counties of Monterey and San Luis Obispo) casual mention is made of salt water encroachment in one or two wells at the lower end of the valley near the shore of Monterey Bay.

"The report also voiced the opinion that little apprehension need be felt concerning the sufficiency of the supply of water for all needed purposes including irrigation, within a stated limit of variation of water levels.

"Fortunately from that time up to the present there has been an average of more than normal rainfall. During this period a large additional acreage in the Valley has been brought under irrigation together with more double cropping, a number of additional irrigation wells have been bored near the Monterey Bay Shore and elsewhere, a large industrial plant using continuously about 1,000 gallons of water per minute has been established there, and some water has been diverted for use on non-overlying lands.

"As a consequence, during recent years an increasing number of wells in that vicinity have become so salty that their use had to be abandoned or at least greatly restricted. In the Spring of 1944 conditions became so bad that a number of farmers and land owners from this area appealed to the Board of Supervisors for help. Under instructions from the Board, County Engineer Howard Cozzens arranged with the State Department of Public Works, Division of Water Resources to make a study of the situation; the cost to be borne equally by the State and Monterey County. In accordance with this understanding, an investigation was commenced by the Division in July, 1944.

"The report which follows gives factual data acquired in 18 months of field work. It also analyzes the present water situation in the Valley from

San Ardo to Monterey Bay as far as available data will permit. Such conclusions as are contained herein should be accepted as coming from the most authoritative source available, namely the office of the State Engineer of the State of California."

Prior Investigations by State and County

The Water Conservation Committee of Salinas Chamber of Commerce became concerned over the apparent depletion of the ground water supplies in the Salinas Basin in 1930 during the last dry period. The committee requested the Division of Water Resources to make an investigation referred to above by Mr. Pioda and if necessary lay out a plan for conservation of a portion of the runoff normally wasting into Monterey Bay. After a preliminary examination it was decided at that time that an investigation should be limited to an effort to determine (1) whether the natural replenishment of the underground basin was adequate to supply the draft, (2) the water requirements of the then unirrigated lands, and (3) the amount of water which could be made available by conservation works. The 1931 legislature appropriated funds for such an investigation, the appropriation to become available as matched by funds locally and deposited in the State Treasury.

The County of Monterey appropriated $5,000 and the County of San Luis Obispo $500 of matching funds toward the conduct of an investigation of the Salinas Basin by the Division of Water Resources in 1931 and 1932. The Division published a report in 1933 entitled, "Report on Salinas Basin Preliminary Investigation", and a supplement entitled "Record of Water Levels at Wells in Salinas Basin".

The 1933 report of the Division summarizes hydrologic information on the Salinas Basin. It refers to and contains a summary of an unpublished report by Geologist Chester Marliave on the geology of all known dam sites in the Salinas River stream system. A conclusion is set forth in the report that the average long time natural replenishment of the underground basin was probably sufficient for a water demand based on use in 1932, but if the draft from 1928 to 1931 was to recur continuously there would exist a permanent overdraft which must in time be remedied. It will be hereafter set forth that the previous peak demand in 1931 was exceeded in 1939, and from 1943 to 1945, inclusive.

It is set forth in the 1933 report by the Division that the quality of water in the Salinas Basin as a whole is excellent, and there appeared at that time no intrusion of salt water from the bay to the pumping strata. It is further stated: "Two things might happen which would impair the quality in the northern end of the valley and more particularly near the ocean: (1) the water plane might

be so lowered that ocean water would penetrate the pumping strata. (2) Since pumping draft has been substituted for natural disposal of water a tendency may be found for the salt content of the underground water to increase. It will be noted that it does increase to the northward." The occurrence of both of these predictions are hereafter set forth.

It was recommended in the 1933 report by the Division in view of the narrow margin of surplus over demand that local interests should continue measurements of water elevations at representative wells in the Salinas Basin. County Engineer Howard F. Cozzens of the County of Monterey has since maintained records of water levels at 116 selected wells in the basin at the commencement and at the close of each irrigation season.

Previous Reports

Six early reports have been published on conditions in Salinas Valley. These are:

(1) Charles D. Marx - Report on Irrigation Problems in the Salinas Valley. This report covers problems incident to gravity diversion systems in Salinas Valley in 1901. Pumping from ground waters was unimportant at that time.

(2) Homer Hamlin - (1904) Water Resources of the Salinas Valley - Water Supply Paper 89. Good information on a few possible reservoir sites are set forth. These were considered from the standpoint of water conservation.

(3) W. O. Clark - (1916) Measurements of Depth to Water in Wells in the Salinas Valley (unpublished). These records were obtained from the U. S. Bureau of Soils and included in the supplement of the Division of Water Resources' report in 1933.

(4) M. H. Lapham and W. H. Heileman - (1901) Soil Survey of the Lower Salinas Valley. This early soil survey covered the area from King City to Monterey Bay in Salinas Valley.

(5) E. J. Carpenter, A. E. Kocher and F. O. Youngs - (1924) Soil Survey of the King City Area. This is a resurvey of the area from Soledad to King City and new survey from King City to Wunpost.

(6) E. J. Carpenter, and Stanley W. Cosby - (1925) Soil Survey of the Salinas Area. This is a resurvey of the area from Soledad to Monterey Bay.

Investigation by Corps of Engineers, U. S. Army

A survey of the entire drainage basin of the Salinas River for flood control and related matters was ordered by the Chief of Engineers, U. S. Army on July 11, 1939. Completion of the comprehensive flood control survey report is awaiting availability of information developed in the concurrent hydrologic investigation of the Salinas Basin by the Division of Water Resources, Department of Public Works, State of California.

In connection with the flood control survey studies, possibilities of channel training and bank protection works were developed that appeared to fit into any general plan of flood control and water conservation, separate consideration of which was warranted. A proposed interim report of the Chief of Engineers, U. S. Army, which gave separate consideration to such works, was referred by the Governor of California through the Director of Public Works to the State Engineer on February 8, 1946 for review and report thereon. The review and report by the State Engineer was included in the views and recommendations of the State of California on the proposed interim report. It was recommended that the project be approved and be authorized by Congress for immediate construction. The Rivers and Harbors Act, enacted in 1946, included the Salinas River channel improvement project, as set forth in the interim report.

Scope of Investigation

The general scope of the Salinas Basin Investigation is set forth in the contract entered into by the State and County. The contract provides for investigation of the water resources of the Salinas Valley in Monterey County and conditions relative thereto which obtain in the valley or affect the water supplies available therefor. It is further provided that the Department shall prepare a report based on the investigation setting forth the physical facts pertinent to water supply and to salt water intrusion, and if possible, incorporating findings as to a method or methods of solving the problems involved.

It was the expressed desire of the county officials that the investigation include a review of the hydrologic conditions in the Salinas Basin since the time of the previous investigation by the Division of Water Resources in 1931 and 1932. Such a review appeared to be necessary in view of probability of current overdrafts on ground waters.

The scope of the investigation was further crystallized by the Division after the completion of the preliminary phase of the work in September, 1944.

There would be no duplication of work done in the previous investigation by the State and County. The scope of the investigation was limited to water conservation problems, since a comprehensive flood control survey was being conducted concurrently by the United States Engineering Department. There appeared to be but little irrigable land in the Salinas Basin in the County, which, when brought under irrigation, would not detract from the source of supply common to the lands presently irrigated. The investigation was limited to a determination and solution of problems involved in maintenance of a water supply adequate both in quantity and quality for all present beneficial uses in the basin and for future uses that offered a threat to further depletion of the common supply.

The first consideration in the Salinas Basin Investigation was ascertainment of whether water problems requiring water conservation actually existed. This involved a determination of overdrafts, if any, on the ground water supplies. After discovery of necessity for water conservation, the investigation was pointed to find the following:

1. Where additional water is needed.
2. How much supplemental water is presently and will ultimately be required.
3. Where the sources of surplus water that waste from the basin are located.
4. What feasible methods are available for capture of a portion of the waste to the bay.
5. How the captured water can be made available for use in areas of overdraft.

A detailed knowledge of the physical situation is necessary in order to appreciate the problems and grasp the solutions that appear.

CHAPTER II

SUMMARY AND CONCLUSIONS

Information collected in the Salinas Basin Investigation, analyses of basic data, and results are set forth in Bulletins 52, 52A and 52B of the Division of Water Resources. Bulletin 52 contains an introductory statement, summary and conclusions, and detailed technical analyses. The introductory statemant includes an account of water resources development in the basin, information leading up to the investigation, a list of prior investigations and reports, and statement as to scope of the present investigation. The results of analyses free of technical discussion, and a concise statement of possible solutions of water conservation problems are set forth in the summary and conclusions. All basic data used in the analyses are published in Bulletin 52A. The Introduction, Summary and Conclusions of Bulletin 52 hsve been reprinted as Bulletin 52B.

Description of Salinas Basin

Knowledge of general physical conditions in the Salinas Basin, reasons for division of the valley floor into five areas, composition of the valley fill, and present development in the area is necessary to appreciate the problems revealed in results of analyses and to grasp the solutions that appear. A brief description of these features follows.

(1) General

The Salinas River system drains a mountain and foothill area of about 3,950 square miles, exclusive of the Soda Lake watershed, which is a closed interior valley with an area of about 660 square miles. The tributary watersheds are grouped for analytical purposes in accordance with runoff characteristics. The main thread of the Salinas River is about 170 miles long and has a general northwesterly course somewhat parallel to the coast to its mouth in Monterey Bay near Castroville.

The lower 93 miles of the Salinas River meanders through the valley floor from near Wunpost to the Bay. The gross area of the valley floor is about 239,000 acres, all in Monterey County. This area is classified into four general groups based on a cultural survey in 1944 as follows:

Group	Area in Acres
Irrigated land	125,423
Irrigable dry-farm and grass land	51,981
Native vegetation	30,419
Miscellaneous	31,195
Total	239,018

All water requirements in the basin for irrigation, domestic, municipal and industrial purposes are supplied from ground water with the exception of a limited acreage near Greenfield, which receives supplemental early season gravity water from the Arroyo Seco, a tributary of the Salinas River. The principal source of replenishment of the ground water is percolation of stream flow in the channels of the Salinas River and its tributaries. There is probably some contribution directly from precipitation on portions of the valley floor in wet years.

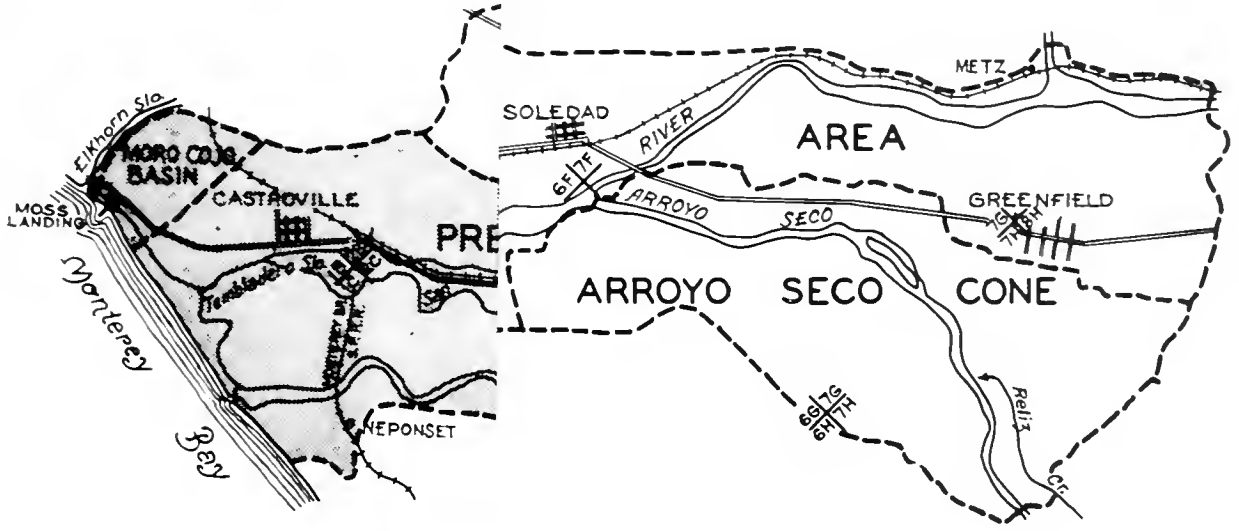
(2) Division of Valley Floor into Five Areas

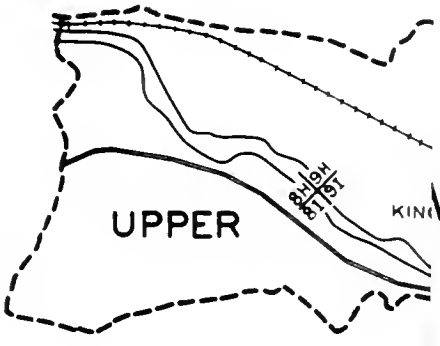
The valley floor was divided into five areas for analytical purposes. The division is in accordance with sources of replenishment of ground water for the respective areas served as indicated by direction of flow of ground water after the close of the 1944 irrigation season. The areas are designated as Pressure, East Side, Forebay, Arroyo Seco Cone, and Upper Valley. The boundaries of the areas are shown on the key map submitted as Plate 1. These areas are not in any way to be confused with sub-basins. All information collected during the investigation indicates the ground waters therein are interconnected with the exception of possible instances of closed lenses in the East Side Area and a more or less effective ground water barrier immediately south of Moro Cojo Slough. The acreages embraced in the respective areas into which the valley floor is divided, as shown on Plate 1, are as follows:

Area	Acreage
Pressure	80,980
East Side	36,477
Forebay	40,373
Arroyo Seco Cone	22,115
Upper Valley	59,073
Total	239,018

The Pressure Area embraces a strip with an average width of about 4-3/4 miles extending southerly from Monterey Bay to Gonzales. The pumping zones in this area are largely supplied by ground water flow from the upstream Forebay Area. With the exception of a pocket of free ground water in the vicinity of Quail Creek, the aquifers in the Pressure Area are partially confined. The confinement appears to effectively prevent percolation to the pumping zone directly from precipitation and from the river channel between Gonzales and the bay. A deep ocean canyon, a short distance offshore in the bay and at right angles to the main axis of the Pressure Area, is probably the northern boundary of the partially confined waters in the area. The confined waters appear to be generally interconnected with the free ground water to the east, which permits inflow and outflow from and to the East Side Area.

PLATE 1





KEY SHOWING

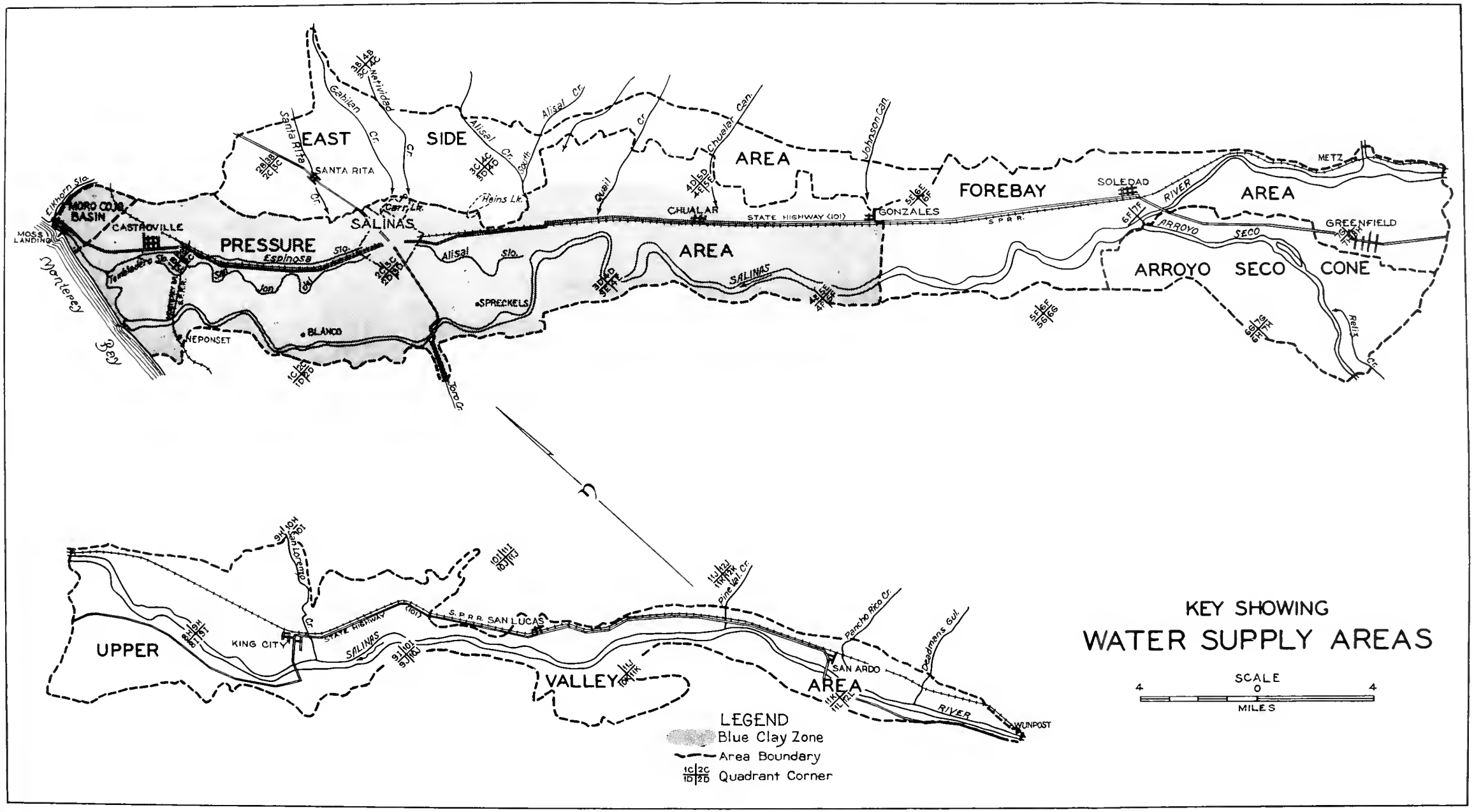
WATER SUPPLY AREAS

SCALE

4 0 4

MILES

PLATE 1


KEY SHOWING
WATER SUPPLY AREAS
SCALE
4 0 4
MILES
LEGEND
Blue Clay Zone
Area Boundary
Quadrant Corner
EAST SIDE AREA
PRESSURE AREA
FOREBAY AREA
ARROYO SECO CONE
UPPER VALLEY AREA
MORO COJO BASIN
MOSS LANDING
CASTROVILLE
SANTA RITA
SALINAS
CHUALAR
GONZALES
SOLEDAD
METZ
GREENFIELD
NEPONSET
BLANCO
SPRECKELS
KING CITY
SAN LUCAS
SAN ARDO
WUNPOST
Monterey Bay
STATE HIGHWAY (101)
S.P.R.R.
SALINAS RIVER
ARROYO SECO RIVER
Santa Rita Cr.
Gabilan Cr.
Natividad Cr.
Alisal Cr.
South Alisal Cr.
Quail Cr.
Chualar Can.
Johnson Can.
Carr Lk.
Heins Lk.
Espinosa Slo.
Alisal Slo.
Toro Cr.
Elkhorn Slo.
San Lorenzo Cr.
Pine Val. Cr.
Pancho Rico Cr.
Deadmans Gul.
Relix Cr.

The principal source of ground water replenishment in the East Side Area is percolation from the channels of streams that head on the west slope of the Gabilan Range between Santa Rita Creek and Johnson Canyon. There may be some contribution to ground water directly from precipitation in the wetter years. There has been surface outflow from the East Side Area in only five of the past 16 years. The entire water crop on the area, under average conditions of rainfall and runoff, is retained there and locally disposed of through evapo-transpiration and percolation. In years when the consumption of ground water in this area exceeds replenishment, the boundary line between the Pressure and East Side Areas tends to move easterly; and conversely, whenever the replenishment exceeds consumption of ground water in the East Side Area, the west boundary thereof tends to shift westerly.

The principal source of ground water replenishment in the Forebay Area is ground water outflow from the Upper Valley Area and the Arroyo Seco Cone. Percolation from the channel of the Salinas River is also important. There is probably no contribution to ground water direct from precipitation on the area, except in very wet years such as 1940-41.

The principal source of ground water replenishment in the Arroyo Seco Cone is percolation from the channels of the Arroyo Seco and its tributary Reliz Creek. A major portion of the water diverted from the Arroyo Seco through the Clark Canal to the Greenfield district percolates to the water table in the cone. Since the average annual precipitation over this area is about nine inches, there is probably no contribution to ground water direct from precipitation on the cone except in very wet years.

The principal source of replenishment of ground water in the Upper Valley Area is stream channel percolation from the Salinas River and its tributaries between Metz and San Ardo. There may be some percolation to the water table from precipitation over the area in wet years. There is no opportunity for any appreciable ground water inflow from the south because the alluvial fill of the main valley terminates at the south end of San Ardo Valley.

(3) Valley Fill

Knowledge of the composition of the valley fill is based on observations of ground water behavior and a study of well logs and well driller information. Logs of 420 wells distributed over the valley floor were identified as to well locations. Several lines of logs plotted along the main axis of the valley and at right angles thereto show the valley fill to be complex with numerous lenses from the side tributaries interspersed within the principal influence of the Salinas River.

The only consistent strata in the fill appear to be two continuous layers of blue clay between Gonzales and Monterey Bay. The blue clay zone appears to average more than 4½ miles in width and abuts the easterly base of the Santa Lucia Range on the westerly edge of the valley floor. There are two aquifers with partially confined waters throughout the blue clay zone. The average depth to near the center of the upper aquifer is about 180 feet and it is referred to as the 180-foot aquifer. There is a stratum of impervious blue clay over-lying the 180-foot aquifer. Another stratum of blue clay separates the 180-foot aquifer from the deeper water-bearing formation, designated the 400-foot aquifer. There were 660 wells operating in 1945, that were perforated exclusively in the 180-foot aquifer, and 37 that tapped only the 400-foot aquifer. There were two wells known to be perforated in both aquifers. The 180-foot aquifer supplies more than 95 per cent of the current total demand for water in the Pressure Area. There may be deeper water-bearing formations below the 400-foot aquifer that have not been explored. The 400-foot aquifer extends farther to the east than the 180-foot aquifer between Carr Lake and Santa Rita. There are inadequate well logs through the 400-foot aquifer in the southerly portion of the Pressure Area to support a conclusion that both aquifers have a common forebay.

The ground waters generally through the East Side, Forebay and Upper Valley Areas and the Arroyo Seco Cone are unconfined. The gravels, sands and silts since deposition in these areas have been in process of change through decomposition to clay. All shades of material are indicated by the logs. Any stratum may range from coarse open gravel to fine sand, sandy and gravelly clays, and clays with varying arrangements in succeeding strata. The clays in these areas of free ground water are yellow or red in color and are in unconnected lenses. Some pockets of water-bearing gravels are under slight pressure due to partial local confinement. Heavy yielding wells with slight drawdowns are generally obtained in these areas. Yields in excess of 200 gallons per minute per foot of drawdown are quite common. However, there are instances of wells of low yield, inadequate to support irrigation draft, which are largely confined to strips of overlap in the outwash of deltas of various tributaries on the east side of the valley.

(4) Present Development

The character and boundary lines of all types of culture on the alluvial fill in the Salinas Basin were mapped in 1944 and again in 1945. The locations of all operating wells and such of the non-operating wells on which well

logs were available or which were used as measuring wells were also mapped during the cultural surveys. Aerial photographic reproductions were used as a base for the surveys.

(a) Crops

Cultural classification of the entire valley floor was made in accordance with estimated normal water consumption. Water-consuming vegetation that has substantially the same consumptive uses was placed in the same class. The grouping included 10 classes of irrigated culture, one of irrigable land, four of native vegetation and five in miscellaneous. A summary of irrigated culture and of potential irrigable land in 1944 follows:

	Acres in Valley Floor Area					
Culture	Pressure	East Side	Forebay	Arroyo Seco	Upper Valley	Total
Alfalfa	2,201	1,978	5,208	2,997	2,018	14,402
Lettuce	19,457	1,952	2,551	353	---	24,313
Truck	9,097	1,414	5,146	1,178	1,515	18,350
Beans	8,926	7,048	5,247	8,374	6,480	36,075
Sugar Beets	3,595	537	1,563	173	9,893	15,761
Artichokes	2,942	---	---	---	---	2,942
Guayule	2,927	1,599	3,102	1,057	98	8,783
Seeds	544	109	---	---	107	760
Orchard	250	281	710	426	1,322	2,987
Grain	151	236	109	45	509	1,050
Irrigated Sub-total	50,090	15,154	23,636	14,601	21,942	125,423
Irrigable dry-farm and grass	12,540	18,815	4,182	2,289	14,155	51,981
Irrigated and Irrigable Total	62,630	33,969	27,818	16,890	36,097	177,404

A total area of approximately 126,700 acres was irrigated in 1945. This represents an irrigation development of about 71 per cent of the total irrigable area in the valley.

Soil surveys were made in 1924 and 1925 in the Salinas Valley by the United States Department of Agriculture, Bureau of Chemistry and Soils. Extensive changes have been made in land uses and irrigation practices in the basin since the time of these surveys. Additional information is now available through more than 20 years of demonstration of the adaptability of the lands to a wide range of crops, of proper irrigation systems to prevent damage from erosion, of necessity for drainage in certain areas and other improvements.

(b) Wells

Since most of the area in the Salinas Valley lies in Spanish land grants, the valley floor was divided into quadrants to facilitate description of well locations. The same quadrant system shown on the 1933 map of the Division of Water Resources was used on the cultural maps. The location of quadrant corners is indicated on Plate 1. The first number and letter of a well designation indicates

the quadrant within which the well is located. The following number indicates the well number within that quadrant. If there is no final letter in the well designation, an operating irrigation well is indicated. Final letters n, m, i, d and p in the well designation respectively indicate "non-operating", "municipal", "industrial", "domestic", and "plugged".

There were 636 operating irrigation wells and 61 industrial and municipal wells in the Pressure Area in 1945. This represented approximately half of the irrigation, municipal and industrial wells in Salinas Valley at that time. There are also numerous non-operating and domestic wells of negligible draft throughout the valley.

Inflow and Outflow

An ascertainment of overdraft involves a determination of the total inflow and outflow to and from the valley floor. The inflow embraces the total water crop, which is made up of surface tributaries and ground water inflow to the valley floor and rainfall directly thereon. There is no importation of water to the valley. The outflow is made up of the total disposition of water on the valley floor and comprises surface and ground water outflow to the bay, all evaporation and plant transpiration within the valley and exportation from the basin. For purposes of hydrologic analyses, a 16-year base period from 1929-30 to 1944-45, inclusive, was used. This 16-year period was used as a base because the average runoff and precipitation were close to the mean of the long time record. Further reasons for using this period are that within it the hydraulic data on inflow, outflow and ground waters are more complete and the current problems have arisen within that time. The Arroyo Seco, on which continuous records of discharge are available during the past 44 years, has been used as guide stream in supplying a runoff index to reproduce the records for the unmeasured tributaries. The average rainfall at Salinas during the past 44 years is almost equal to the 72-year mean. The precipitation at Salinas has been used as an index for determination of the average seasonal precipitation on the valley floor each year during the 16-year base period.

(1) Water Crop

The average annual total water crop received by the valley floor during the 16-year base period has been determined to be approximately 946,000 acre-feet. This amount has been derived from sources directly tributary to the five areas in the valley floor approximately as follows:

Water Crop in Acre-Feet

Area	Surface Tributary Inflow	Rainfall on Valley Floor	Marine Intrusion	Lateral Percolation
Upper Valley	516,000	52,000	0	Negligible
Arroyo Seco Cone	133,000	18,000	0	Negligible
Forebay	14,000	32,000	0	Slight
East Side	6,000	43,000	0	Negligible
Pressure	32,000	94,000	6,000	Slight
Total	701,000	239,000	6,000	Negligible

That portion of the water crop directly tributary to the Upper Valley Area and Arroyo Seco Cone, which was not retained in those areas, flowed into the Forebay Area. Also that portion of the water crop tributary to the Forebay and East Side Areas, which was not retained in these areas, flowed into the Pressure Area.

(2) Outflow

The average annual total outflow from the basin during the 16-year base period was determined to be approximately 533,000 acre-feet. This is made up as follows:

Source	Average Outflow Acre-feet
Salinas River at Spreckels (measured)	476,000
Toro Creek and foothills to the northwest	6,000
East Side Area via Tembladero Slough	1,000
Rainfall runoff from valley floor below Spreckels	7,000
Irrigation Return and sewage effluent	13,000
Ground water	30,000
Exportation	Negligible
Total	533,000

The single item of measured surface outflow of the Salinas River near Spreckels makes up approximately 90 per cent of the total outflow from the basin.

(3) Retention and Consumption

The difference between the average total water crop and the outflow indicates an average annual retention in the valley floor of about 413,000 acre-feet during the 16-year base period, which figure includes the estimated average marine intrusion of 6,000 acre-feet per annum and precipitation on the valley floor.

The average annual retention of water plus or minus the average change in ground water storage during the 16-year base period is a measure of the average annual water consumption on the valley floor for the period. There was no appreciable change in ground water storage during the base period except a decrement in the East Side Area and in the fringe of free ground water in the

easterly portion of the Pressure Area, which approximated 30,000 acre-feet. The average annual decrement in ground water storage was about 2,000 acre-feet for the period, which added to the average annual retention, by this method of approach indicates an average annual consumption of 415,000 acre-feet. Use of the integration method as an independent approach to determine the average consumption of water during the period closely checked the inflow-outflow method.

The retention of water in the valley floor in 1944-45 was approximately 383,000 acre-feet and decrease in ground water storage was about 50,000 acre-feet, which indicates a total consumption in that year of 433,000 acre-feet. The average acreage under irrigation during the 16-year base period was about 107,000 acres as compared with 126,700 acres irrigated in 1945.

Percolation

Observations of retention of surface inflow from the Arroyo Seco within the Arroyo Seco Cone during the period from October 1, 1944 to September 30, 1945, were used as a basis for a formula to calculate the annual percolation from that stream in the cone during the 16-year period. The average annual percolation was calculated to be approximately 51,000 acre-feet, which represents about 40 per cent of the average inflow from the Arroyo Seco. A portion of the surface outflow from the Arroyo Seco Cone into the Salinas River also percolates in the Forebay Area. The natural regulation of the inflow through percolation from the Arroyo Seco in 1944-45 was about 60,000 acre-feet, which represents 58 per cent of the total inflow during that year.

The combined stream flow percolation during the 16-year base period in the Upper Valley and Forebay Areas was calculated as a differential. A summary of the calculated average stream flow percolation that has occurred in various portions of the valley during the 16-year base period follows:

Area	Average Percolation Acre-Feet
Arroyo Seco Cone	51,000
Upper Valley and Forebay (combined)	163,000
East Side	5,000
Pressure	1,000
Total	220,000

(1) Ground Water Movement

The average ground water movement from all areas in the valley, except the Upper Valley, during the 16-year base period was calculated as follows:

Area	Acre-feet
Arroyo Seco Cone	31,000
Forebay	91,000
East Side (net)	0
Pressure (net)	30,000

Ground water may move either from the East Side to the Pressure Area, or from the Pressure to the East Side Area depending on the time of the year and the degree of wetness of the year. The net effect during the period has probably been an average annual ground water outflow from the Pressure Area to the East Side Area in the order of 1,000 acre-feet.

(2) Sources of Surplus Water

An average annual discharge of approximately 444,000 acre-feet, or about five-sixths of the total outflow from the Salinas Basin, has during the 16-year base period flowed from the Forebay Area in the form of surface waste. About one-third of the remaining one-sixth has occurred as ground water outflow to the bay largely during the winter season when irrigation demand was light. The remaining estimated average annual waste has the following sources:

Source	Waste in Acre-Feet
Tributaries North of Arroyo Seco	36,000
Outflow from rainfall on valley floor	10,000
Irrigation return and sewage	13,000

Surface wastes from tributaries to the valley north of the Arroyo Seco and from precipitation on the valley floor are unreliable. The outflow from these two sources is negligible in years that are slightly subnormal in precipitation. The irrigation return and sewage outflow, which occur in the blue clay zone of the Pressure Area, are comparatively steady under prevailing irrigation practices. This latter source might provide some firm water in the Pressure Area.

Approximately 80 per cent of the total surface inflow from watersheds tributary to the East Side Area during the 16-year period has been retained in that area. There was 100 per cent natural regulation through percolation of the flows of these streams in 11 out of 16 years. The small average surplus water in these streams occurs so infrequently that consideration of enhancement of the supply through local development in the area is unwarranted. A complete solution of the problems of overdraft must include salvage of a portion of the large surface outflow from the Forebay Area.

Underground storage within the 60-foot zone below ground surface in the order of 100,000 acre-feet, on which draft has never been made, exists in the Forebay Area and the lower portion of the Arroyo Seco Cone.

Underground Hydrology

The study of the underground reservoir of the Salinas Valley includes a determination of rates of safe yield and overdraft in the Pressure Area with contamination from marine intrusion as the controlling factor. The study also embraces

consideration of unconfined waters in the valley fill to define areas where present draft exceeds average annual recharge, and to ascertain the location and extent of surplus underground storage.

(1) Fluctuations in Water Levels

There was a fluctuation in water levels at wells in the 180-foot aquifer in the Pressure Area of about 15 feet during the irrigation seasons of 1944 and 1945. All but less than one foot of the average recovery in water levels at wells in the aquifer after the close of the irrigation season in 1944 occurred prior to any replenishment of ground water in the basin from percolation of stream flow and precipitation. The small average recovery of less than one foot after the Salinas River commenced to flow during the winter of 1944-45 indicates little seasonal depletion in the supply to the aquifer from the Forebay Area in 1944. The seasonal depletion was slightly greater in 1945 than during the previous year. It is concluded that fluctuations in water levels and hydraulic gradient in the 180-foot aquifer are largely governed by pressure relief induced by draft. Seasonal depletion of ground water storage in the Forebay Area above the blue clay zone has a minor effect in years close to normal, such as 1944 and 1945.

There has been no important change in storage of unconfined ground waters in Salinas Valley during the past 16 years, except in the East Side Area and in the Quail Creek section of free ground water included in the Pressure Area. The aquifers in the blue clay zone in the Pressure Area remain saturated at all times. Water levels in the Upper Valley and Forebay Areas have had a narrow range of fluctuation of about six feet between the low in 1931 and the high in 1941. The estimated average recession in water levels during the past 16 years in the East Side Area was about five feet and in the free ground water in the Quail Creek section of the Pressure Area was about 10 feet.

(2) Draft

The consumption of water, expressed in unit values of feet in depth per acre, has been determined by the Division of Irrigation of the Soil Conservation service for various cultural classifications under irrigation practices prevailing during 1944-45 in the different areas in the valley. The unit values were determined for normal climatic conditions and also under the conditions prevailing during the years 1943-44 and 1944-45. A summary of average unit values of normal consumptive uses, expressed in feet in depth per acre follows:

Consumption of Ground Water and Precipitation on Valley Floor

Area	Irrigated	Irrigable Dry-Farm and Grass*	Native Vegetation	Miscellaneous
Pressure	1.69	1.10	3.81	1.73
East Side	1.86	1.10	4.51	1.10
Forebay	2.17	.75	2.68	1.53
Arroyo Seco Cone	2.12	.75	3.10	.73
Upper Valley	2.13	.83	2.47	1.88
Entire Valley	1.93	.99	2.94	1.59

*Average annual precipitation on valley floor is approximately equal to consumption by irrigable dry-farm and grass.

The determined unit values of consumptive uses in 1943-44 and 1944-45 expressed as percentages of the above normal unit values follow:

Area	Per Cent of Normal	
	1943-44	1944-45
Pressure	99.0	100.5
East Side	99.0	100.5
Forebay	98.3	99.6
Arroyo Seco Cone	98.3	99.6
Upper Valley	97.8	100.0

The unit values of normal consumptive uses were applied to the estimated average acreages in the various cultural groups during the 16-year base period to obtain the approximate average consumption in each area in the valley during the period. The 1944-45 unit values were applied to the acreage irrigated in 1945 to obtain the consumption in that year. The comparative results follow:

Area	Consumption in Acre-Feet	
	16-year Average	1944-45
Pressure	141,000	149,000
East Side	48,000	53,000
Forebay	78,000	81,000
Arroyo Seco Cone	38,000	40,000
Upper Valley	109,000	110,000
Total Valley	414,000	433,000

It may be noted that the above 16-year average consumption in the entire valley of 414,000 acre-feet obtained by this method closely checks that previously calculated by the inflow-outflow method.

The estimated amount of pumping from ground water in 1944-45 to supply a portion of the above consumption was about 353,000 acre-feet for irrigation purposes and 14,000 acre-feet for domestic, municipal and industrial uses.

The pumping in 1943-44 was estimated to be about 448,000 acre-feet for irrigation purposes and 13,000 acre-feet for domestic, municipal and industrial uses. It is estimated that more than 90 per cent of the domestic, municipal and industrial pumping was in the Pressure Area. The estimated pumping for irrigation use in the various areas during each of the two years follows:

Area	Ground Water Pumped in Acre-feet	
	1943-44	1944-45
Pressure	104,000	107,000
East Side	33,000	34,000
Forebay	77,000	77,000
Arroyo Seco Cone	47,000	48,000
Upper Valley	87,000	87,000

The domestic, municipal and industrial pumping in the Pressure Area was about 12,000 acre-feet in 1943-44, and 13,000 acre-feet in 1944-45.

(3) Overdrafts

The only overdrafts on ground water in the Salinas Valley are in the East Side and Pressure Areas. There is no present shortage of ground water in the remainder of the basin and no threat of deficiency under probable ultimate development.

(a) East Side Area

The total consumption of water within the East Side Area was about 52,000 acre-feet in 1943-44 and 53,000 acre-feet in 1944-45. Direct precipitation on the area respectively supplied about 38,000 and 39,000 acre-feet in 1943-44 and 1944-45. Consumption of ground water within the East Side Area approximated 14,000 acre-feet during each of the two years. Excluding consideration of the net difference in ground water inflow and outflow (which is believed to be small), consumption of ground water within the East Side Area during the 2-year period exceeded replenishment by approximately 23,000 acre-feet. Under normal conditions of consumption and replenishment and with demand based on cultural classifications prevailing during the 2-year period, the overdraft would be in the order of 7,000 acre-feet per annum. The normal consumption of ground water in the adjoining area of 5,000 acres overlying free ground water in the Pressure Area is about 3,000 acre-feet per annum. The only ground water replenishment during the 2-year period for this latter area was escape of water from the partially confined aquifers in the Pressure Area.

An approximate area of 18,000 acres of dry-farm and grass land in the East Side Area offers the greatest possibility for expansion of irrigated lands in the Salinas Basin. The possibility for increased annual consumption of ground water in this area is in the order of 14,000 acre-feet under maximum development.

The ultimate overdraft, including that estimated to presently exist, may approach 21,000 acre-feet per annum.

(b) Pressure Area

A direct method of determination in 1944-45 of rate of flow through the 180-foot aquifer in the Pressure Area was used. This involved collection of the following information:

1. Periods of lag in stabilization of water levels in the aquifer after changes in rates of draft;
2. Positions of trough in pressure surface elevations; and
3. Draft above and below the trough in the pressure surface.

The determined rates of flow through the 180-foot aquifer showed wide variations under different conditions of draft. Under an average minimum draft of 17 cubic feet per second for three weeks the rate of flow appeared to be about 85 cubic feet per second with an approximate rate of outflow to the bay of 68 cubic feet per second. An average maximum rate of draft of about 330 cubic feet per second prevailing for three weeks appeared to induce a rate of flow down the valley of about 275 cubic feet per second and a rate of infiltration of sea water from the bay of about 55 cubic feet per second. Under conditions of draft generally dispersed throughout the Pressure Area, the safe yield rate of draft on the 180-foot aquifer was calculated by this direct method to be about 230 cubic feet per second. Varying conditions of draft concentrations may cause variations in the rate of safe yield. The combined rate of draft from the 180-foot aquifer in 1945 exceeded the rate of safe yield for a period of more than six months during the irrigation season. The rate of excess draft varied from about 15 to 100 cubic feet per second between April 8 and October 13, in 1945. The overdraft was made up by movement of water through the aquifer toward the inland from Monterey Bay. The cumulative amount of marine intrusion during this period in 1945 was about 12,000 acre-feet. However, the cumulative amount of the excess in rate of total draft over and above the rate of safe yield in 1945 was about 20,000 acre-feet. This latter quantity represents the approximate amount of water that must be substituted for present draft on the aquifer in order to eliminate actual overdraft. Actual overdraft is equal to the cumulative difference between downstream flow of water through the aquifer, and safe yield, plus marine intrusion. Substitute water to eliminate actual overdraft should be available over a 6-month period at rates up to a maximum of 100 cubic feet per second to prevent marine intrusion.

The ultimate overdraft on the 180-foot aquifer, including that estimated to presently exist, may approach 55,000 acre-feet per annum less such addi-

tional water as may be extracted from the 400-foot aquifer under safe yield conditions. The annual outflow from the 400-foot aquifer and other water bearing formations, if any, in addition to the 180-foot aquifer and surface water zone was estimated as 8,000 acre-feet in 1944-45. This comparatively small waste, a substantial portion of which occurs during the winter season, makes it unsafe to assume that the deeper water-bearing formations offer much toward a solution of the problems other than temporary relief.

Quality of Water

Approximately 97 per cent of the estimated total percolation from stream flow, during the 18-year base period, occurred in the area south of Gonzales. In this area about 70 per cent of the runoff normally comes from the Santa Lucia Range below Paso Robles. Waters emanating from the Santa Lucia Range are of good quality, whereas those coming from the Diablo Range have comparatively high concentration of solubles.

The quality of the waters in the Salinas River above Gonzales is most important during two different periods of the year when greatest contribution to water occurs. A rapid rate of percolation occurs from the first river flow during the runoff season following cessation of fall irrigation when water levels in the free ground water areas are near the low point for the year. A rapid rate of percolation from the river also occurs after the commencement of the irrigation season on or about the first of April and continues until the river flow fails. Fortunately the early and late flows in the Salinas River are usually supplied entirely from tributaries heading on the Santa Lucia Range where the precipitation is approximately twice that on the Diablo Range. The east side streams coming from the Diablo Range ordinarily do not commence to flow during the winter season until substantially full recharge of ground water has occurred in the areas supplied by river percolation. Only that portion of ground water formations lying east of the Salinas River influence between Metz and San Ardo usually receives replenishment from surface waters containing high concentrations of salts. The contaminated ground waters in the easterly portions of the San Lorenzo and Pancho Rico deltas may be accounted for by the salinity in the sources of replenishment.

There is a general increase in salinity in the Salinas River during the course of its flow from San Ardo toward Monterey Bay. The quality of water during periods of low flow is largely influenced by the ground water inflow. The summer flow below Blanco is too saline for irrigation use. Likewise the dry

weather season flows in tributaries to Tembladero Slough are unsafe for irrigation use with the exception of Espinosa Slough, which is largely made up of industrial wastes of fair quality.

(1) Contamination in Forebay Area

The amount of water pumped for irrigation use in the Forebay Area in 1944 has been estimated as about 77,000 acre-feet. The consumption of water on the irrigated land during the irrigation season in 1944 was about 35,000 acre-feet. The precipitation during the summer season in 1944 on the irrigated land in that area supplied about 2,000 acre-feet of consumptive uses. The unconsumed irrigation water in the amount of approximately 44,000 acre-feet largely returned to the pumping zone. This represents nearly half of the estimated ground water movement from the Forebay Area. A large part of the replenishment in the Forebay Area is made up of ground water flow from the Upper Valley Area and Arroyo Seco Cone. The Forebay Area thus ultimately receives unconsumed irrigation water applied to all irrigated lands in the valley south of Gonzales. The unconsumed irrigation water becomes charged with natural soil solubles and applied fertilizers, which are carried to the pumping zone. The ground water flow from the area is limited by the bottleneck at the head of the adjacent Pressure Area. The quality of water throughout the Forebay Area is quite spotted, ranging from excellent to fair. The type of ground water solubles apparently accumulating in various portions of the Forebay Area is similar in character to the contamination from surface water (perched water) in the vicinity of Salinas in the Pressure Area.

(2) Normal Good Water in Pressure Area

The normal good water in the 180-foot aquifer is restricted to a belt between a line about two miles inland from the bay and a short distance south of Blanco. Analyses of samples from six control wells in this belt show substantially no change in quality of water between 1932 and 1944. The average of analyses of samples from 35 wells in this belt in 1944 with mineral concentrations ranging from about 350 to 450 parts per million has been taken as indicative of normal good water in the 180-foot aquifer.

A reconnaissance of quality of water in the 400-foot aquifer in 1944-45 failed to reveal any contamination in this water-bearing formation. Total solubles run quite uniform between about 275 and 325 parts per million. Laboratory analyses of samples from three wells indicate excellent quality of water in this aquifer for irrigation, municipal and industrial uses.

(3) 180-Foot Aquifer [illegible]

All samples of water collected from wells in the [illegible] in 1944-45 south of Blanco showed extreme [illegible] in that aquifer. Samples from [illegible] wells showed [illegible] 1200 to 1900 parts per million. The character [illegible] belt is quite similar to that in the Pressey Area [illegible] centration of solubles. The upper limit for safe use for irrigation [illegible] solubles for this type of contamination appears to be about 1700 parts per million. Heavy soils with slow drainage predominate in this area and the rainfall is normally inadequate to cause leaching of salt concentrations from the top-soil.

(4) Marine Intrusion

Marine intrusion has occurred in the 180-foot aquifer in recent years as a result of overdraft. There was no evidence of such contamination in October, 1945 at any well more than 1-3/4 miles from the bay shore. The average distance of the fringe of contamination from the bay shore at that time was about 1½ miles. The total length of the contaminated strip, including the Moro Cojo sub-basin in the Moss Landing Area, was about 6½ miles. The gross area embraced within the zone of contamination was approximately 6,000 acres, about 25 per cent of which was in the Moss Landing Area. The wells within about half of the contaminated zone contain waters that are presently either unusable for irrigation, or are near the upper limit in salinity for safe use.

The inland rate of encroachment of the fringe of contamination was slow between August 1944 and August 1945. The average movement during this period of one year was about 600 feet. Although the rate of encroachment was slow during that time, the concentration of salts rapidly increased in wells of heavy draft within the zone of contamination. Chlorides more than doubled in the water solubles in many of the wells during the year. Pumps of low draft for domestic purposes may skim off water of good quality from the top of the aquifer where there are no nearby wells of heavy draft to surge the salinity to the upper waters.

The maximum distance that marine intrusion may encroach in the 180-foot aquifer is the most inland position of the trough in the pressure surface under conditions of heaviest draft. If water supply and draft conditions in 1945 were maintained indefinitely, salinity encroachment might approach, but not extend beyond a line, which would embrace between it and the bay shore an area of about 9200 acres irrigated in 1945. The small difference in head due to difference in specific gravity of water on both sides of the fringe of contamination would have negligible effect on the distance of encroachment.

Evaluation of Water Problems

The average annual total water crop received by the valley floor in the Salinas Basin, exclusive of marine intrusion, is approximately 940,000 acre-feet. The normal annual total consumption of water on the valley floor under present stage of development is about 433,000 acre-feet. This may approach 509,000 acre-feet under ultimate development. The average amount of unconsumed water under present and ultimate development shows availability of large local water supplies to solve the water conservation problems. Total consumption, as herein used, includes all evapo-transpiration on the valley floor from precipitation and from surface and ground water supplies, as distinguished from draft, which is limited solely to consumption of ground water. It is necessary to consider safe yields of ground water supplies under existing conditions in the various areas and drafts thereon to evaluate the problems.

Primary sources of ground water troubles are overdrafts. Deterioration in quality of water and receding water levels are manifestations of overdraft. Present and estimated ultimate irrigated acreages and annual drafts, and safe yield of ground water supplies under existing conditions in the various areas on the valley floor are summarized in the following tabulation:

Area	Irrigated Acreage		Draft in Acre-feet		Safe Yield
	Present	Ultimate	Present	Ultimate	Acre-feet
Upper Valley	22,000	36,000	58,000	76,000)	190,000
Forebay	23,800	27,800	49,000	55,000)	
Arroyo Seco Cone	14,800	16,800	22,000	25,000	51,000
East Side	15,900	33,900	12,000	26,000	5,000
Pressure	50,200	62,600	103,000	138,000	83,000
Total	126,700	177,100	244,000	320,000	------

The foregoing tabulation shows safe yield in excess of estimated ultimate drafts in the Upper Valley, Forebay and Arroyo Seco Cone Areas. However, such excess in safe yield, under existing conditions, is not available to make up the deficiency in the East Side and Pressure Areas due to the bottleneck at the lower edge of the Forebay Area, which limits the rate of ground water outflow therefrom. The safe yield in the Forebay Area may be materially increased through establishment of greater ground water movement from that area, as hereafter discussed.

Present and estimated ultimate overdrafts in the East Side and Pressure Areas and wastes that occur from the basin are summarized as follows:

Item	Acre-feet
Present combined overdrafts	27,000
Ultimate combined overdrafts	76,000
Average annual surface outflow	503,000
Average annual ground water outflow	30,000

A salvage in the order of five per cent of the average total outflow would eliminate present overdrafts. Ultimate demand may necessitate salvage which would approach 15 per cent of the average total outflow.

Methods of Conservation

Methods of conservation that appear possible of incorporation in a solution of water problems in the Salinas Basin are hereafter briefly discussed. The methods deal both with salvage of wastes to relieve overdrafts and protection of quality of ground waters.

Surface reservoir sites on the Arroyo Seco, San Antonio River, Nacimiento River, and the Salinas River south of San Ardo are receiving attention in the current flood control survey by the Corps of Engineers, U. S. Army. Development of surface storage for water conservation hinges on the suitability of the site for flood control. When and if surface storage is developed in the Salinas Basin south of Soledad for flood control purposes, consideration should be given to benefits that may be received from participation therein for purposes of water conservation.

(1) General Available Methods of Salvage

Salvage of applied irrigation water unconsumed on crop land in the Pressure Area can best be accomplished by increasing the irrigation efficiency so as to eliminate all pumping in excess of beneficial requirement. Outflow from irrigation return is limited to the blue clay zone in the Pressure Area. Drainage from the blue clay zone is not susceptible of re-use due to the generally prevailing high concentration of solubles. The indicated method of salvage is elimination of unnecessary pumping, which would reduce the occurrence of waste by a corresponding amount. The total amount of applied irrigation water unconsumed on irrigated crop land in the blue clay zone was in excess of 50,000 acre-feet in each of the two years 1943-44 and 1944-45. The portion of such water unconsumed on irrigated crop land, which may properly be included in beneficial requirement, has not been determined.

The effluent from the sewage disposal plant of the City of Salinas is near the borderline of safety for irrigation use. Dilution of the effluent with water pumped from the 400-foot aquifer would probably make it safe for irrigation use. The amount available for use in 1945 during the irrigation season was in the order of 2,000 acre-feet. Annual carrying charges on the combined effluent and dilution water were estimated at $2,500. The combined flow during the irrigation season of about 3,000 acre-feet, while small, would have low unit cost.

Packing shed washwater and ice plant cooling water in and near Salinas is mostly discharged into Espinosa Slough. About half the total average discharge of approximately 12 cubic feet per second during 1945 was pumped from the slough for irrigation re-use. The water is of fair quality. Due to probability of further deterioration in quality and a liklihood of eventual abandonment of water cooling at ice plants in the area, the salvage may be classed as a temporary supply providing about 1,000 acre-feet during the irrigation season. Cost of salvage for use on abutting lands would be nominal.

Some attention was given to the matter of inducing increased percolation in the Arroyo Seco Cone in the 1933 report by the Division of Water Resources. Further consideration was given in the recent investigation to increased percolation in other areas of free ground water. In any event a complete solution of the problems of overdraft must include salvage of some of the surface waste from the Forebay Area. There was almost complete failure of surface outflow from the Salinas Basin during five years of record since 1912. (1913, 1924, 1931, 1933 and 1939.) Additional water for use in critical dry years obviously is dependent on cyclic storage either in surface reservoirs or underground. Cyclic storage underground is generally preferable where empty storage capacity exists, or where space for additional natural percolation may be created by draft on unused underground storage.

Underground storage exists in the Forebay Area and in the lower portion of the Arroyo Seco Cone in the order of 100,000 acre-feet within the 60-foot zone below ground surface on which no draft has ever been made. Empty capacity for underground storage existed in the East Side Area in 1945 between the water table and the 60-foot zone below ground surface in the order of 200,000 acre-feet. A comparable additional capacity then existed in the East Side Area between 60 and 12 feet below ground surface.

The Forebay Area and lower portion of the Arroyo Seco Cone are favorably situated in respect to areas of overdraft in the basin for utilization of unused underground storage to eliminate the deficiencies. The underground reservoir also has a strategic location for flexible operation in conjunction with direct diversion from the Salinas River and released surface storage from any important reservoir site in the stream system with the exception of those on the Arroyo Seco. Diversion from underground storage should be restricted to territory south of the head of the 180-foot aquifer a sufficient distance to prevent drawdown from having any material effect on the existing ground water flow through the Pressure Area.

(2) Conservation of Quality of Water

Further protective measures pointed toward conservation and improvement of quality of water supplies in the Salinas Basin deserve equal consideration with those designed to maintain adequacy in quantity. Slow movement of ground water operates against rehabilitation after contamination has occurred. Many "defective wells" in the older irrigated sections in the basin are either still in operation, or have been abandoned without being properly plugged. The term "defective well", as here used, means any well drilled, dug or excavated, which encounters unpotable water, or water containing substances toxic to crop plants, and which is so constructed as to permit the commingling of such contaminated water with waters of better quality, or a flowing well which lacks the necessary devices to control waste of water therefrom.

There are acceptable methods for preventing construction of defective wells and also for repair of defective wells if they are to be continued in use. The construction of defective wells as above defined should of course be prohibited. Any existing defective wells, which are to be continued in use, should be repaired. Whenever a defective well is abandoned it should be plugged under competent supervision.

In order to enable intelligent action under the foregoing protective measures, standards for uniform logging of wells should be adopted. All well logs should be filed with a central governmental agency within a limited time after completion.

As far as is known there are no defective wells in the 400-foot aquifer. There are doubtless many defective wells in the 180-foot aquifer, long since abandoned, that either cannot be found, or which it would be impractical to clean and effectively plug. However, establishment of protective measures would tend to retard contamination from surface water.

Proposed Solution

Irrespective of the method of salvage employed to capture some of the surface outflow from the Forebay Area, a complete solution must embrace a plan of delivery of water impounded, either in surface or underground reservoirs, to locations where additional water is required. Released surface storage and increased percolation in the stream beds south of Gonzales, without artificial means of conveyance, would be ineffective to relieve overdrafts in the East Side and Pressure Areas. No site was found for gravity diversion from the Salinas River between San Ardo and Monterey Bay. Diversion from the lower 93 miles of the river appears

to be limited to pumping installations. Pumping plants so located that direct diversion of surplus spring flow from the river, released surface storage, and unused underground storage could be diverted for conveyance to locations of overdraft, would offer ideal flexibility.

Favorable sites for diversion wells appear to be situated in the vicinity where the course of the Salinas River changes from the east toward the west side of the valley about three miles southeast of Soledad. The yields of wells with 16-inch casings near the river in this location range from 100 to 300 gallons per minute per foot of drawdown with capacities up to about 2,800 gallons per minute. Water diverted in this location and raised to elevation about 265 feet on the bench north of the river could be conveyed by gravity to a major portion of the East Side Area and to any point in the Pressure Area. The estimated average gross pumping lift at this site would be about 100 feet.

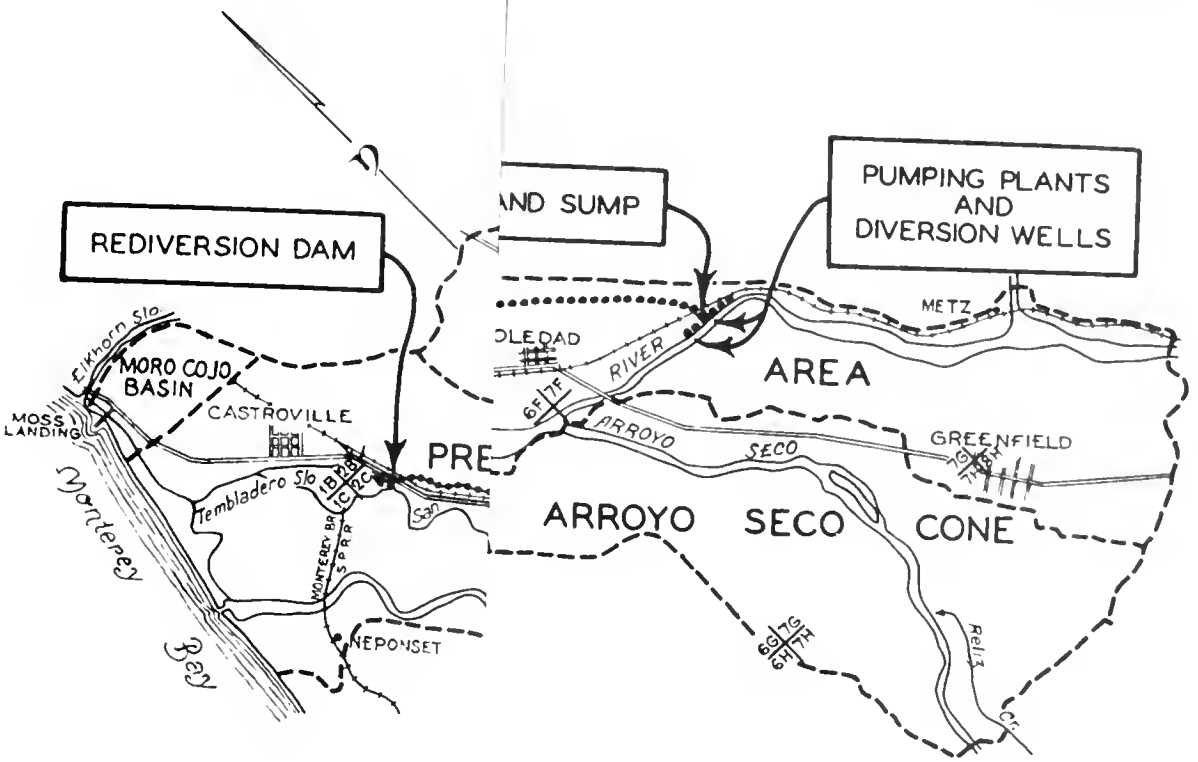
A diversion system heading at this location was selected for a reconnaissance to calculate approximate costs of construction as of the end of the year 1945. More detailed surveys might demonstrate other possible routes to be more feasible.

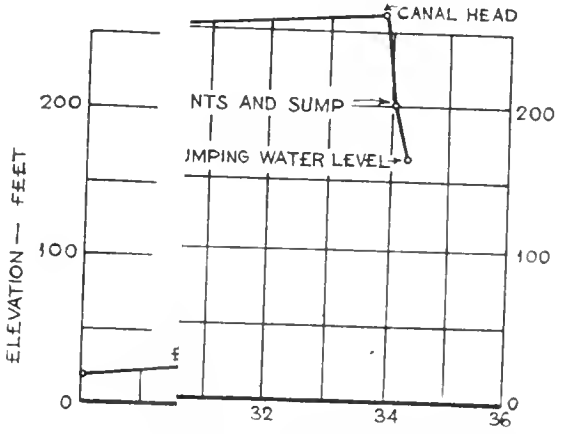
(1) Description of Diversion System

The layout of the proposed diversion system is indicated on Plate 1A. The estimated initial headworks would embrace 36 diversion wells with 16-inch casings drilled to an average depth of 200 feet. Each would be equipped with a deep well turbine type pump with a 60-foot column to deliver water to a centrally located sump. Each pumping plant would have a capacity between 1800 and 2000 gallons per minute for a range in total pumping lift from 20 to 45 feet. Estimated average total lift is 35 feet. There would be six initial booster units installed, each with a capacity of 25 cubic feet per second, to elevate water from the sump to the head of the diversion conduit. The total booster lift would be fairly constant at about 65 feet.

The diversion conduit from its head for a distance of 23 miles to the South Branch of Alisal Creek would consist of a concrete lined canal with a capacity of 250 cubic feet per second for 12 miles and then would have a gradual reduction in capacity to 150 cubic feet per second in the next 11 miles. The flow would be conveyed down the South Branch of Alisal Creek to a rediversion dam where a portion would be diverted and conveyed northerly six miles to Natividad Creek through an unlined canal with capacity of 80 cubic feet per second. The remaining water would be conveyed down natural and canalized channel to a regulating reservoir in

PLATE 1A



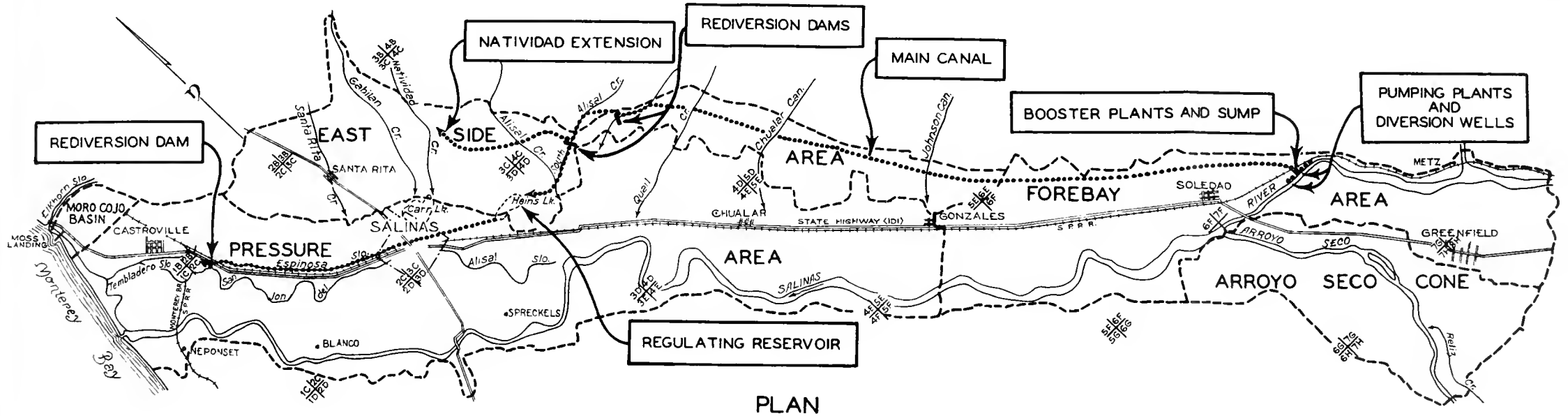


ED DIVERSION SYSTEM

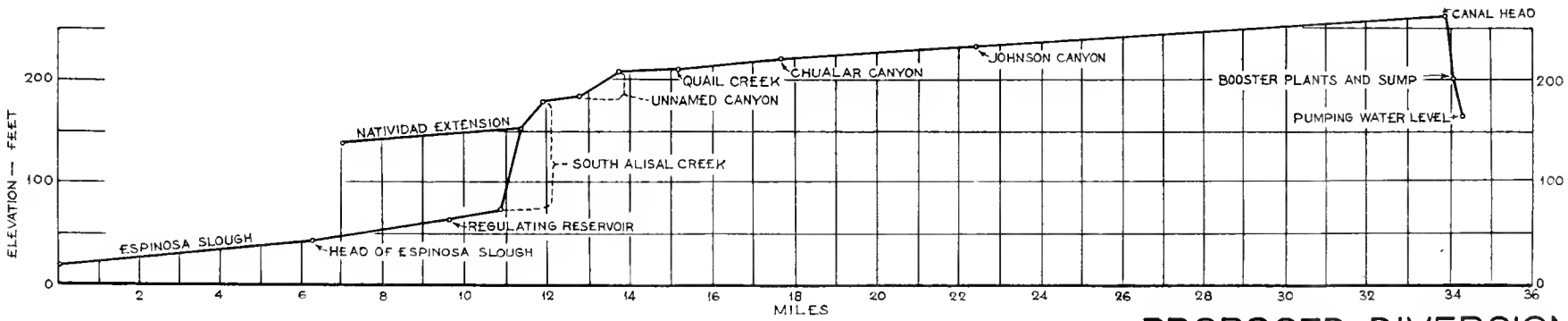
0 MILES 5

LEGEND

- Area Boundary
- 1C | 2C / 1D | 2D Quadrant Corner
- Conduit Route



PLAN



PROFILE

PROPOSED DIVERSION SYSTEM

5 0 5
MILES

LEGEND
- Area Boundary
- 1C | 2C / 1D | 2D Quadrant Corner
- Conduit Route

Heins Lake with a capacity of 300 acre-feet. A portion of the water would be conveyed from the regulating reservoir through concrete pipe for tie-in and service through existing distribution systems in the Salinas area and the remainder would be conveyed to the head of Espinosa Slough at Highway 101 crossing. Espinosa Slough would be used to convey water to the Salinas-Castroville Highway crossing where water would be rediverted and delivered through concrete pipes for tie-in to and service through existing distribution systems in the area of marine intrusion.

The main canal between Johnson Canyon and the South Branch of Alisal Creek and the Natividad Extension would be equipped with checks, take-outs, distribution pipe lines and valves to effect tie-in to and service through existing distribution systems below the conduit in the East Side Area. Thirty county and farm road bridges and flumes for crossing 10 creeks would be included in the system.

The foregoing initial development would utilize in average years under current demand approximately 17,000 acre-feet of direct diversion from the Salinas River prior to June 15. Average annual draft on underground storage through the proposed diversion system under current demand would be about 28,000 acre-feet after the river ceased to flow through the Forebay Area.

(2) Diversion System Offers Solution

The primary purpose of such a diversion system, as above suggested, would be for direct use through existing distribution systems in areas of overdraft in lieu of draft on local supplies. An initial diversion of 45,000 acre-feet during the irrigation season would provide about 25,000 acre-feet of substituted supply for the East Side Area and 20,000 acre-feet in the Pressure Area where serious contamination from perched water and marine intrusion has occurred, and in the section of free ground water supplied by escape from confined waters. Normal annual consumption of ground water in the East Side Area for acreage presently irrigated is about 12,000 acre-feet compared with annual replenishment from local tributaries of about 5,000 acre-feet. Unconsumed irrigation water largely returns to the pumping zone in the East Side Area. The combined local and substituted supplies would provide an estimated annual contribution to cyclic underground storage of 16,000 acre-feet. Such cyclic storage would be available for emergency use within the area and no physical difficulty would be encountered in recapture and transfer for use in the Pressure Area in years of extreme drouth.

An accumulation of cyclic underground storage in the East Side Area would reverse the present direction of ground water movement from the Pressure

to the East Side Area. The East Side Area may eventually assume its former capacity of serving as a lateral forebay to the Pressure Area thereby causing an increase in present flow of water through the partially confined aquifers. This would result in escape of some cyclic underground storage but such outflow would not be wasted.

Draft on unused underground storage from the Forebay Area would establish more movement of ground water therefrom, a highly desirable condition. It would tend to improve the quality of water therein by inducing greater percolation of surface flows of the Salinas River and the Arroyo Seco. About 88 per cent of the total surface outflow from the basin would be available for natural recharge of the underground reservoir.

Adequate unused underground storage is immediately available to meet all present requirements for additional water in areas of overdraft. Continued observations of general effect on ground water as a result of increased draft from the Forebay Area would allow a more accurate evaluation of the amount of surface storage required under ultimate development in the Salinas Basin. The foregoing estimates of necessary salvage are to be taken as approximations subject to more accurate determination during the course of development of the solution of the problems.

(3) Estimated Cost of Diversion System

Estimated costs were based on unit costs as of the end of the year, 1945. Unsettled labor conditions and unstable prices of materials may cause substantial and rapid changes in construction costs during the post-war period.

The initial construction of the diversion system, on which a cost analysis was made, would have a pumping capacity of 150 cubic feet per second. Additional units would be installed as demand for water increased. The lined canal would be constructed with a capacity of 250 cubic feet per second. The cost analysis includes diversion wells, pumping plants, regulating reservoir, supplemental distribution systems, rediversion dams from natural channels, clearing natural channel, and construction of main canal and crossings. The estimated cost includes rights of way, 25 per cent for engineering and contingencies, and interest during construction at 3 per cent. The total cost for initial development, based on prices at the end of the year 1945, is estimated at $2,117,000.

Annual carrying charge on initial costs was computed with interest at 3 per cent and amortization in 40 years. Power costs for pumping, including additional cost of pumping under existing plants in the Forebay Area, were computed

on the basis of rates effective in 1945 for electric power service in the Salinas Valley. Annual charges on clearing natural channel were based on one complete clearing per 10-year period. Annual maintenance on pumps, motors and diversion wells were calculated on the basis of 3 per cent of initial cost of installation. Depreciation on pumps and motors is based on replacement in 25 years. Allowance for general maintenance each year was made on the basis of one per cent of the balance of construction costs. Demand for water under the initial installation was based on substitution of 25,000 acre-feet in the East Side Area and 20,000 acre-feet in the Pressure Area during each irrigation season, where present average power costs for water were estimated to be about $2.90 per acre-foot.

Based on prices at the end of the year 1945, the total annual costs of the substituted supply are estimated at $226,400 for 45,000 acre-feet under the proposed initial installation. The cost per acre-foot of substituted supply is estimated at $5.00. No effort is made in this report to apportion among the various water users in the basin the difference in cost of water to users, who would receive direct service from substitute water. It is estimated that approximately 35 per cent of the substitute water would go to cyclic underground storage, which would benefit all water users in the East Side and Pressure Areas.

When and if surface storage under a dual-purpose project becomes available for release to maintain recharge of ground water in the Forebay Area, the item in carrying charges of increased cost of pumping to overlying lands in the Forebay Area, estimated at $15,000 per annum, would be eliminated. Such released storage would also decrease annual power costs for pumping under the proposed diversion system in an amount estimated at $9,000.

Legal Considerations

The foregoing analyses have been based strictly on engineering principles. Successful consummation of plans embracing a complete solution of water conservation problems involves more than engineering. The existence of numerous overlying landowners and appropriators in the basin creates legal obstacles to development designed to salvage waste.

The development of the ground waters in the Salinas Basin has been typical of that by individual effort in many other areas. It has proceeded without supervision or adequate information of results on the part of those using the water. Such information usually comes after alarm is caused by deterioration in quality of water and receding water levels. and frequently after a series of lawsuits, which may be inconclusive.

Underground water is presumed to be percolating water and the burden of proof is upon the party claiming to the contrary. Ground water flowing through definite underground streams are subject to the same laws as streams with surface flow. The English common law rule of absolute ownership of percolating waters on the part of the overlying owner was abrogated in 1903 by the California Supreme Court. Katz v. Walkinshaw, 141 Cal. 116. The principles therein declared, and as developed in subsequent decisions, have come to be known as the California doctrine of correlative rights. The correlative doctrine of rights of landowners overlying percolating waters is comparable in many respects to the doctrine of riparian rights of owners of lands contiguous to water courses. The two doctrines became more closely analogous after adoption of the Constitutional amendment in 1928, Calif. Const. Art. XIV, Sec. 3, which imposed reasonable use upon riparian as well as ground water uses. Knowledge of the fundamental principles of the correlative doctrine is essential to an appreciation of the legal obligations imposed by law on users of percolating waters under overdraft conditions.

(1) Rights of Way and Financing

As previously stated, any complete solution of overdraft problems in the basin will necessitate an extensive diversion system from the Salinas River. This will involve rights of way through several holdings. It may be anticipated that some of the rights of way cannot be obtained without condemnation proceedings. It will also be necessary to raise funds to finance construction, operation and maintenance of works.

(2) Comprehensive Adjudication Under Water Code

Increase in irrigation efficiency by elimination of extractions for non-beneficial uses would give direct relief to overdraft on the 180-foot aquifer and would retard current marine intrusion. This is also a vital step toward conservation of quality of ground water throughout the basin, which is threatened by excessive leaching of top soil. The expeditious and certain method of increasing irrigation efficiency is through a comprehensive determination of rights to extract ground water under the court reference procedure. (Sections 2000 to 2050, inclusive, of the Water Code). Through this adjudication procedure, which is comparatively inexpensive, elimination of extractions of water in excess of quantities required for beneficial use can be secured as well as uniform observance of the rule of reasonable use as enjoined by Section 3, Article XIV of the Constitution.

The court reference procedure permits the reference of any water right case to the Department of Public Works, acting through the State Engineer, for investigation and report to the court upon any or all of the issues. This procedure has been recommended to the superior courts in many recent water law decisions of the California Supreme Court. The details of the procedure were reviewed and approved in Fleming v. Bennett, 18 Cal. (2d) 518.

Several benefits would be derived from a comprehensive determination of rights to pump ground water in the basin other than elimination of extractions in excess of beneficial requirement. It would afford a basis for assessment, pro rata in accord with benefits received, of costs of providing a water supply necessary to enable a complete solution of water conservation problems. It would also stop the running of the statute of limitations and prevent impairment of legal rights of claimants to water whose rights may be in the process of being adversed by prescription. A comprehensive adjudication would give stability to water right titles and establish a basis for orderly progress of development of a complete solution of the water problems.

(3) Use of Underground Reservoirs

A complete solution of water conservation problems in the Salinas Basin, as previously explained, may include utilization of two natural underground reservoirs. One of these situated in the Forebay Area has a large surplus of unused underground storage and the other in the East Side Area has empty capacity for storage. In regards the right to use underground reservoirs where storage capacity already exists and can readily be made available, a case in point is Los Angeles v. Glendale, 142 Pac. (2d) 289 (1943). It is stated at page 294 in that decision as follows:

> "It would be as harsh to compel plaintiff to build reservoirs when natural ones were available as to compel the construction of an artificial ditch beside a streambed."

The proposed plan, involving utilization of unused underground storage, includes compensation of overlying owners in the Forebay Area for increased costs of operation, although estimated ultimate demand would require use only within the 60-foot zone below ground surface. It was stated in Peabody v. Vallejo at page 496, 40 Pac. (2d) as follows:

> "....The correct rule is stated with its appropriate limitations in the italicized words in the following language of the District Court of Appeal in Waterford I. Dist. v. Turlock I. Dist., 50 Cal. App. 213, at page 221, 194 P. 757, 761: 'The mere inconvenience, or even the matter of extra expense, within limits which are not unreasonable, to which a prior user may be subjected, will not avail to prevent a subsequent appropriator from utilizing his right.'" (Note underlined portion was italicized).

Prior users are subject to extra expense within reasonable limits and it might be ruled by a court that the item of additional cost of pumping under existing plants in the Forebay Area should be borne in whole or in part by the users in that area rather than by users who would receive direct service from substitute water.

Conclusions

The conclusions in this report with reference to the future conditions are based on the following general assumptions:

> (a) That all irrigable land in the Salinas Valley will ultimately be brought under irrigation, (b) the net change in types of irrigated crops and irrigation practices will not materially alter the average annual water consumption per acre of irrigated land in the areas of free ground water, (c) the average amount of water pumped per acre of irrigated land in 1944 in the blue clay zone will remain constant and that increased pumping for new irrigation will not increase return to the pumping zone, but will be disposed of by evapotranspiration and outflow to the bay, (d) water utilization on town and farm lots is substantially the same as the average on irrigated land in the area, and (e) rainfall and water supply will have annual and cyclic variations as in the past.

It has been concluded from analyses of available data as follows:

1. The average annual total water supply, including rainfall but exclusive of marine intrusion, received by the valley floor in the Salinas Basin approximates 940,000 acre-feet.

2. Normal annual total consumption of water on the valley floor under present stage of development is about 433,000 acre-feet. This may approach 509,000 acre-feet under ultimate development.

3. There are no present or prospective overdrafts on ground water supplies in the Arroyo Seco Cone, Forebay and Upper Valley areas.

4. Present and estimated ultimate normal annual drafts on ground water, safe yield of ground water supplies under existing conditions and annual overdraft in the East Side and Pressure Areas approximate the following amounts:

Area	Draft in Acre-feet		Safe Yield	Overdraft in Acre-feet	
	Present	Ultimate	Acre-Feet	Present	Ultimate
East Side	12,000	26,000	5,000	7,000	21,000
Pressure	103,000	138,000	83,000	20,000	55,000
Total	115,000	164,000	88,000	27,000	76,000

5. Average annual surface outflow from the Salinas Basin of about 503,000 acre-feet provides a large local water supply to solve the water conservation problems. A major portion of the average annual ground water outflow of about 30,000 acre-feet occurs during the winter season and is not susceptible of salvage.

6. Surface storage in the Salinas River stream system south of Gonzales, or increased percolation in the Arroyo Seco Cone, with no supplemental works to recapture respectively released surface storage or the percolate for use in areas with deficient supplies, would be ineffective. Such development would probably be offset by a comparable increase in surface outflow and natural disposal of other inflow to the Forebay Area with a net result of little or no salvage of wastes for beneficial uses.

7. Any complete solution of the water conservation problems must embody utilization of a portion of the average annual surface outflow from the Forebay Area of about 444,000 acre-feet. Any complete solution must also embrace a diversion system from the Salinas River to the East Side and Pressure Areas. (The layout of a proposed diversion system is indicated on Plate 1A.) The outflow from the East Side Area is not worthy of consideration in a plan of conservation due to infrequency of occurrence and inadequacy in total amount.

8. Cyclic storage is necessary to provide additional water for use in the Salinas Basin in critical dry years. Empty underground reservoir capacity in the order of 400,000 acre-feet, which is usable for cyclic storage, exists in the East Side Area. Any ground water outflow during the irrigation season from underground storage in the East Side Area would be available for use in the Pressure Area where a current deficiency prevails. This would result in comparatively high efficiency in recapture of cyclic underground storage for use.

9. Undergrouhd storage within the 60-foot zone below ground surface in the order of 100,000 acre-feet, on which draft has not been made, exists in the Forebay Area and the lower portion of the Arroyo Seco Cone.

10. A proposed diversion system designed to annually divert and convey under initial installations 45,000 acre-feet of unused underground storage from the Forebay Area for direct use in areas of overdraft in lieu of draft on local supplies in the East Side and Pressure Areas offers a solution of present water conservation problems. Total cost per acre-foot, including operation, maintenance, interest and amortization based on prices at the end of year 1945, of such substitute water is estimated at $5.00. Estimated average cost of power alone for

water from existing supplies in areas of overdraft is $2.90 per acre-foot. Approximately 16,000 acre-feet of such substitute water would, after direct use, annuelly go tc cyclic underground storage.

11. After completion of the current flood control survey by the Corps of Engineers, U. S. Army, a feasible plan of dual-purpose surface storage may be developed, which would permit diversion of released surface storage for direct use and provide a greater amount of cyclic underground storage for emergency use in critical dry periods. The above proposed diversion system, which would be necessary in any event to provide a complete solution of water conservation problems, would fit in with and be an integral part of such duel-purpose surface storage.

12. Excessive leaching of top soil in the valley south of Gonzales because of low irrigation efficiency is resulting in an accumulation of salinity in the ground water in the Forebay Area. A large part of the replenishment in the Forebay Area is made up of ground water inflow from the Upper Valley Area and Arroyo Seco Cone which contains leachings from irrigation waters unconsumed in those areas. Increase in irrigation efficiency is a vital step toward conservation of quality of water throughout the basin. The above proposed diversion system would also tend to improve quality of water in the Forebay Area.

13. Conservation measures for protection of quality of ground watera should be preventive rather than corrective because of semi-permanent nature of damage after contamination has occurred. Protective provisions may be established by law and enforced through legal measures prescribing uniform standards for logging of wells, recordation of well logs, repair of operating defective wells and plugging of abandoned defective wells under competent supervision.

14. Salvage of wastes resulting from extractions in excess of beneficial requirement, general conservation of quality of ground water through elimination of excessive leaching of top soil, stabilization of water right titles, and orderly progress in development of a complete solution of water conservation problems would require a comprehensive adjudication of rights to pump in the basin.

15. Problems of overdraft are not necessarily the sole concern of those being damaged by deterioration in quality of ground water, recession in water levels, and operation of prescription. The California doctrine of correlative rights applicable to percolating waters imposes obligations on users of percolating waters to share the burdens when there is not enough water for all.

16. Plans to meet present and ultimate requirements for water in the Salinas Basin can and should be accomplished by an orderly progression of phases of development. Successive steps in a comprehensive plan call first for salvage of available wastes with lowest unit cost, and thence in order of expense for recourse to methods of greater unit cost. The more expensive water may in this manner be held to a minimum in the final phase of development.

17. In order to supply the mechanics for solution of the problems involved, it would be necessary to create a local water authority or public district endowed with appropriate powers.

CHAPTER III

DESCRIPTION OF SALINAS BASIN

The Salinas River system drains a mountain and foothill area embracing approximately 3,950 square miles above the alluvium in the valley floor of the basin in Monterey County. The Soda Lake watershed, which is a closed interior valley with an area of 660 square miles, is not included in the tributary system. The main thread of the Salinas River is about 170 miles long and has a general northwesterly course somewhat parallel to the coast to its mouth in Monterey Bay about two miles west of Castroville. The lower 83 miles of the river meanders through the valley floor proper from the southerly portion of the San Ardo Valley to the bay.

Tributary Watersheds

There are three important tributaries to the Salinas River from the west. These are the Nacimiento and San Antonio rivers and the Arroyo Seco. Estrella and San Lorenzo creeks are tributaries of lesser importance from the east. A tabulation of these and other minor tributary areas follows:

Tributary Areas	Drainage Area Square Miles
(Headwaters)	
Salinas River above Paso Robles	389
(West Side Watersheds)	
San Marcos Creek	31
Nacimiento River	343
San Antonio River above Pleyto	283
San Antonio River below Pleyto and Hames Valley	87
Garrissere Gulch to 7-Wells Canyon	18
Kent Canyon to Reliz Creek	85
Arroyo Seco above valley floor	231
Limekiln Creek to Pine Canyon	63
West Side foothills above Spreckels	150
Toro Creek	43
Foothills north of Toro Creek	18
(East Side Watersheds)	
Huerhuero Creek	156
Estrella Creek	954
Mahoney Canyon to Lowes Canyon	21
Indian Valley to Vineyard Canyon	136
Deadman's Gulch to Hare Canyon	95
Pancho Rico Creek	61
Sweetwater to Redwood Canyon	95
San Lorenzo Creek	234
San Carlos to Pinolito Canyon	29

Tributary Areas	Drainage Area Square Miles
(East Side Watersheds) Cont'd.	
Chalone Creek	141
McCoy Canyon to Shirttail Canyon	35
Gabilan Creek to Johnson Canyon	107
Santa Rita Foothills	20
Foothills south of Santa Rita	125
Total	3,950

Toro Creek and the foothills north of Toro Creek on the west side of the valley floor are tributary to the Salinas River below the gaging station near Spreckels. The watersheds from Gabilan Creek to Johnson Canyon and the Santa Rita foothills are tributary to Tembladero Slough which flows into Monterey Bay via the old mouth of the Salinas River north of Moss Landing.

The Santa Lucia Range with crest elevations ranging between 3,500 and 5,000 feet separates the Salinas Basin from the Pacific slope. The basin is separated from the San Joaquin Valley on the southeast by the Diablo Range and from the San Benito Valley on the northeast by the Gabilan Range, which ranges respectively have peaks about 5,000 and 3,100 feet in elevation. The Santa Lucia Range, due to a greater annual precipitation, is more thickly covered with native vegetation of oak, pine and dense brush than the mountains on the easterly side of the basin. The average depth of precipitation in the mountains west of the basin is estimated to be nearly double that on the east side. Water supply studies hereinafter set forth in detail indicate that approximately 70 per cent of the total runoff from the watersheds to the valley floor normally comes from the west side mountains and foothills between Spreckels and Paso Robles.

Valley Floor

The Salinas Valley is the largest of the intermountain valleys of the coast range. The valley proper extends from about three miles south of San Ardo to Monterey Bay near Castroville. The valley floor slopes at a fairly even gradient from an elevation of 10 feet near the bay shore to 50 feet at Salinas and 450 feet at San Ardo. There are several pockets of alluvium upstream from San Ardo Valley along the Salinas River and its tributaries. The gross area of alluvium in the main valley embraces approximately 239,000 acres, all in Monterey County. There are several sloughs, swamps, and marshes in the northerly portion of the valley in the Salinas-Castroville area.

The total area of alluvial fill in the Salinas Basin has been classified into four general groups based on a cultural survey in 1944 as follows:

Group	Area in Acres
Irrigated land	125,433
Irrigable dry-farm and grass land	51,991
Native vegetation	30,419
Miscellaneous	31,195
Total	239,018

The above miscellaneous acreage includes areas in perennial water surface, river channel that is normally dry about seven months per year, waste land with no vegetation, town and farm lots, and roads and railroads. The banks of the Salinas River and the bottom land adjoining the channel are largely covered with growth of willows, cottonwoods, baccharis and other native vegetation varying in density from heavy to sparse.

The climate of the Salinas Basin is mild and typical of the central coastal region of California. Approximately 82 per cent of the mean precipitation at Salinas has occurred in the 5-month period from November 1 to March 31. The average dates between killing frosts over a period of 40 years has been March 17 and November 22, which has embraced an average growing season of 250 days. The average dates between killing frosts at King City over a period of 32 years has been April 10 to November 7. The average precipitation on the valley floor between Gonzales and Monterey Bay has been estimated to be about 13 inches, between Gonzales and Greenfield about 9 inches, and between Greenfield and San Ardo about 10 inches. Irrigation is of supreme importance in the maintenance of the type of agriculture that prevails in the Salinas Basin, because of the low average total precipitation and the small portion thereof that normally occurs during the growing season. Climatic features of the basin are further discussed hereinafter in Appendix C.

Salinas, the county seat, and King City are the principal urban centers in the Salinas Basin. Salinas had a population in 1940 of 11,586 and King City 1,708. There have been marked increases in these urban areas since 1940 due primarily to military activities. The important towns between Salinas and King City are Spreckels, Gonzales, Soledad and Greenfield. The industrial development in the basin is largely based on the agricultural economy. The sugar beet factory at Spreckels has an approximate capacity of 5,000 tons of beets per day. Other manufacturing establishments devoted to the processing of agricultural produce are dehydration, packing and ice plants, canneries, creameries, milk condenseries and bakeries. The magnesium plant at Moss Landing is an important development during the recent war period.

The Coast Line of the Southern Pacific Company from San Francisco to Los Angeles extends through the Salinas Basin from Castroville through San Ardo to Santa Margarita. The Monterey Branch Railroad follows near the shore line of Monterey Bay from Castroville to Pacific Grove. Another branch line extends from Salinas to Spreckels. State Highway numbers 41, 101, 152, 175 and 198, together with numerous improved county roads provide an excellent transportation system over the basin. A project for a fishing harbor at Moss Landing was authorized by the River and Harbor Act (Federal) approved March 2, 1945. The Salinas River is not a navigable stream.

Substantially the entire economy of the Salinas Basin is predicated on an adequate supply of ground water of good quality. With the exception of supplemental early season gravity water in the Greenfield area through the Clark Canal from the Arroyo Seco, all water requirements in the basin for irrigation, domestic, municipal and industrial purposes are supplied from ground water. The principal source of replenishment of the ground water is percolation of stream flow in the channels of the Salinas River and its tributaries. There is probably a small contribution directly from precipitation on portions of the basin in wet years.

Division of Alluvium into Ground Water Areas

The alluvial fill in the Salinas Basin has been divided into five areas for analytical purposes in accordance with the sources of replenishment of ground water as indicated by contours of water elevations based on water levels prevailing after the close of the irrigation season in 1944. Measurements were made at that time of depths to water at 520 wells more or less evenly spaced over 239,000 acres for an average of one observation to about 460 acres of alluvium. The contours of water elevations were drawn at 2-foot intervals on a scale of one inch to 1,320 feet. The boundaries of the five areas based on sources of ground water replenishment are indicated on the key map submitted as Plate 1 on page 13 of this report. The areas are designated as (1) Pressure, (2) East Side, (3) Forebay, (4) Arroyo Seco Cone, and (5) Upper Valley. A description of each area follows:

(1) The Pressure Area embraces 80,980 acres between Gonzales and Monterey Bay. The area is bounded on the west by the westerly fringe of the alluvial fill at the easterly base of the Santa Lucia Range. The average distance to the east boundary of the Pressure Area from the westerly edge of the valley floor is approximately 4 3/4 miles. The total length of the area is about 26 miles. This area is bounded on the south by the Forebay Area, and on the east by the East Side Area.

The ground water in the water-bearing formations in the commercial zones of pumping in the Pressure Area is largely supplied by ground water flow from the Forebay Area. With the exception of a pocket of free water table in the Quail Creek area, the aquifers in the Pressure Area are partially confined. The confinement appears to effectively prevent percolation directly from precipitation and from the river channel to the aquifers between Gonzales and Monterey Bay. The free water table area of about 5,000 acres in the vicinity of Quail Creek, supplied exclusively in 1944 and 1945 by ground water movement from the Forebay Area, may receive contributions directly from precipitation and through percolation from Quail Creek in wet years. The contours of water elevations indicate a minor contribution of ground water to the Pressure Area from a small lateral forebay area on the west side of the valley in the sand ridge immediately southwest of Neponset Station on the Monterey Branch Railroad.

There is an ocean canyon more than 600 feet in depth in Monterey Bay that heads opposite the old mouth of the Salinas River a short distance north of Moss Landing. The canyon has a southwesterly course right angles to the main axis of the Pressure Area, and is more than 1,000 feet in depth about three miles northwest of Mulligan Hill opposite the present mouth of the river. If the water-bearing formations in the Pressure Area are not effectively sealed from contact with sea water, ground water contributions from the bay are possible whenever the

elevation of the pressure surface is below mean sea level.

(2) The East Side Area embraces 36,477 acres between the Gloria Road that leads east from Gonzales and Merrit Lake between Santa Rita and Castroville. This area is bounded on the west by the Pressure Area and on the south by the Forebay Area. The East Side Area abuts the westerly base of the Gabilan Range along the easterly fringe of the alluvial fill in the basin.

The principal source of ground water replenishment in the East Side Area is percolation from the channels of streams that head on the west slope of the Gabilan Range between Santa Rita Creek and Johnson Canyon. There may be some contribution directly from precipitation in wet years to the unconfined ground water throughout the area. The estimated average mean precipitation of 13 inches over the area, which is largely well distributed over a 5-month period, is probably inadequate to allow any percolation to the water table.

There has been surface outflow from the East Side Area into the Pressure Area in only five of the past 16 years. The entire water crop on the East Side Area is normally retained there and locally disposed of through evaporation, plant transpiration and percolation. In years when the consumption of ground water in this area exceeds the replenishment, the boundary line between the Pressure and East Side Areas tends to move easterly; and conversely, whenever the replenishment exceeds the consumption of ground water in the East Side Area, the west boundary thereof tends to shift westerly.

(3) The Forebay Area embraces 40,373 acres of unconsolidated alluvium between Gonzales and the bluff line about two miles south of Greenfield. This area is the full width of the alluvial fill between Gonzales and Soledad. The west boundary of the Forebay Area follows along close to Highway 101 between Soledad and Greenfield. The east boundary is the easterly fringe of the alluvial fill between the Gloria Road and Metz. It adjoins the Pressure Area on the north, the Arroyo Seco Cone on the west, and the Upper Valley Area on the south.

The principal sources of ground water replenishment in the Forebay Area are percolation from the Salinas River and ground water outflow from the Upper Valley Area and the Arroyo Seco Cone. Since the average mean precipitation over the Forebay Area is only about nine inches, there is thought to be no contribution to ground water from precipitation on the area, except in very wet years such as 1940-41. The channel of the Salinas River laterally crosses from the east to the west side of the valley in the central portion of the Forebay Area in the vicinity of Soledad.

(4) The Arroyo Seco Cone embraces 22,115 acres on the west side of the Salinas Valley between Ex-Mission Soledad and the bluff line about two miles south of Greenfield. The westerly boundary abuts the easterly base of the Santa Lucia Range. It adjoins the Forebay Area on the north and east and the Upper Valley Area on the south.

The principal source of ground water replenishment in the Arroyo Seco Cone is percolation from the channels of the Arroyo Seco and its tributary Reliz Creek. A major portion of water diverted from the Arroyo Seco through the Clark Canal to the Greenfield district percolates to the water table in the Arroyo Seco Cone. Since the average mean precipitation in this area is about nine inches, there is probably no contribution to ground water from precipitation on the cone except in very wet years.

The channel of the Arroyo Seco is a broad gravel wash between the head of the cone and its confluence with the Salinas near the outer fringe of the cone eight miles to the north. Reliz Creek is tributary to the Arroyo Seco in the upper portion of the cone.

(5) The Upper Valley Area embraces all of the alluvial fill in the valley floor between the bluff line about two miles south of Greenfield and the south end of San Ardo Valley, a short distance north of Wunpost. The gross acreage in the area is 59,073 acres.

The principal source of replenishment of ground water in the Upper Valley Area is stream channel percolation from the Salinas River and its tributaries between Metz and San Ardo. The average mean precipitation of 10 inches over this area is probably inadequate to cause any contribution to ground water from this source. There may be some percolation to the water table from precipitation over the area in wet years. There is no opportunity for any appreciable ground water inflow from the south because the alluvial fill of the main valley terminates at the south end of San Ardo Valley.

Cultural Surveys

The character and boundary lines of all types of culture on the alluvial fill in the Salinas Basin were mapped in 1944 and 1945. The locations of all operating wells and such of the non-operating wells on which well logs were available or which were used as measuring wells were also mapped during the cultural surveys.

Aerial photographic reproductions of the 1938 survey made by the United States Department of Agriculture were used as a base for the cultural surveys in the preparation of work sheets on a scale of one inch to 660 feet. The 1944 aerial photographs taken by the United States Engineer Office were used to establish the location of the channel of the Salinas River and the boundaries of the classes of native vegetation along the river. After mapping the culture, well locations and identification of other detail, photostatic reductions were made of the work sheets and the results of the surveys were combined into a map consisting of six sheets covering the entire area of alluvium in the Salinas Basin on a scale of one inch to 1,320 feet. Duplicate tracing paper reproductions of the six map sheets of the 1944 cultural survey were used for weight determinations of acreage as hereinafter described.

Finished tracings of photostatic reductions of the 1945 cultural survey have been made on a scale of two inches to one mile in five sheets. Lithographic reductions of these map sheets are submitted as Plates 2 to 6, inclusive, in Division of Water Resources Bulletin 52A containing basic data collected during the investigation.

(1) Cultural classification of the entire area in alluvial fill in the Salinas Basin was made in accordance with estimated normal water consumption. Water-consuming vegetation that had substantially the same consumptive uses were placed in the same class. Classification and designation of vegetative and other areas adopted for the mapping were as follows:

Irrigated Land

(a) Alfalfa and clover

(A) Artichoke

(b) Beans

Irrigated Land (Cont'd)

(g) Guayule

(gi) Irrigated grain

(l) Lettuce and celery

(M) Seed and miscellaneous

(o) Orchard

(sb) Sugar beets

(t) Vegetable truck

Irrigable Land

(df) Dry-farm and grass

Native Vegetation

(BH) Dense trees, brush and weeds

(BM) Medium trees, brush and weeds

(BS) Sparse brush, weeds and grass

(S) Swamp, tules and marsh

Miscellaneous

(WS) Water surface

(rc) River channel

(Wl) Waste land

(TL) Town and farm lots

(R) Roads and railroads

The classes of water-consuming areas in the alluvial fill of the Salinas Basin for the year 1945 are respectively designated on Plates 2 to 6, inclusive in Division of Water Resources Bulletin 52A by the above bracketed designation letters. The boundaries of each class are shown with a dotted line. All lands irrigated in the basin in 1945 are depicted in green on the plates in Bulletin 52A.

Most of the area in the Salinas Basin lies in Spanish land grants. The Division of Water Resources divided the area in the valley floor into quadrants, as shown on the map prepared in 1933, which facilitates description of well locations. The same quadrants have been shown on Plates 17 to 21, inclusive, hereof, to make the well descriptions in the 1933 report correspond to those in this report. Each quadrant is approximately 4 5/8 miles wide in an east and west direction and 5 3/4 miles long in a north and south direction. The letters "B" to "L" have been used to designate the north and south coordinates, beginning with "B" near the shore of Monterey Bay and running consecutively up the valley to "L" near San Ardo. Numbers "1" to "12", inclusive have been used to designate the east and west coordinates, beginning with "1" for the most westerly coordinate and running consecutively to "12" in the most easterly quadrant shown on the map. The first number and letter on each Division of Water Resources well number, (hereinafter abbreviated as "D.W.R. Well No.") indicate the map quadrant within which the well is located.

(2) Acreage Determinations in each cultural classification in the 1944 cultural survey were effected by the map weighing method. Duplicate tracing reproductions were used for weight determinations of acreage. The varying hydroscopic moisture content of the paper used

under differing conditions of temperature and humidity and consequent variation in weight of unit areas was ascertained to be relatively unimportant.

A key scale, embracing an area of 125 square inches equivalent to 5,000 acres, was drawn on each of the six original tracing sheets comprising the 1944 cultural survey map. The first step in acreage determination by the map weighing method involved cutting up a set of duplicate tracings along the boundaries of the key scales and of the five water supply areas in the gross alluvial fill of the valley floor. The Forebay Area was further divided into the Upper and Lower Forebay along the line of the Salinas River where its course changes from the east to the west side of the valley floor. The division of the Forebay Area into two parts was necessitated by reason of varying allowances for road and railroad deductions as hereafter explained.

The second step in the acreage determination involved separate weighings of the cut-out key scales and of the assemblies of the water supply areas. It is assumed that the weights so determined are directly proportional to the surface areas represented by them. This assumption presupposes uniform thickness and density of the material of the map. The results obtained indicate that the assumption was justified since the error due to variations of this nature was negligible.

The third step in the acreage determination involved the cutting of each water supply area along the boundaries of each cultural classification therein. The cut-out parts were then assembled by classification groups in each water supply area and these assemblies were then separately weighed with intermittent weighings of the key scales interspersed in the process to check changes in moisture content of the paper. The summation of the areas in the cultural classifications were checked against the previously determined total acreage in each water supply area. The weighing was done to to the nearest one-tenth milligram, which was equivalent to approximately one-ninth acre. The greatest discrepancy between the initial weighing to determine the total acreage in water supply areas and the respective total of the sum of separate weights to ascertain cultural areas was less than 0.5 per cent. The accuracy of the acreage determination by weighing is thought to be superior to the accuracy of mapping delineation and determination by use of a planimeter. Use of the weighing method rather than planimetering resulted in a saving in expense and time of about two man-months.

The fourth step in the acreage determinations involved deductions of allowances for roads and railroads from all irrigated and irrigable gross acreages to ascertain the net areas in these classifications. No deduction was made for the gross acreages in native vegetation and in miscellaneous classification since the net approximated the gross acreages as determined by weighing. A deduction for roads and railroads from gross irrigated and irrigable areas in the Upper Forebay Area and the Arroyo Seco Cone of five per cent was made, and of four per cent in the remainder of the basin.

The net acreage results of the 1944 cultural survey in the Salinas Basin have been tabulated in Table 4 submitted in Appendix A at the end of this report. A comparison of the 1944 and 1945 cultural surveys indicated the general variations in culture were too slight to warrant the expense of a separate determination and tabulation of the acreages in the 1945

cultural classifications. The results of the 1945 survey are depicted on Plates 17 to 21, inclusive, at the end of the report. There was an increase in 1945 over 1944 of approximately one per cent in the total irrigated acreage in the Salinas Basin and a corresponding reduction in the irrigable area.

Soils

Refer nce is made to two publications of the United States Department of Agriculture, Bureau of Chemistry and Soils, for a description of the soils in the Salinas Basin. These publications are entitled "Soil Survey of King City Area, California--Series 1924" and "Soil Survey of the Salinas Area, California--Series 1925". It is outside the scope of this report to duplicate any information heretofore set forth in publications of governmental agencies.

Extensive changes have been made in land uses and irrigation practices in the Salinas Basin since the time of the above mentioned soil surveys. Additional information is now available through more than 20 years of demonstration of the adaptability of the lands in the basin to a wide range of crops, of proper irrigation systems to prevent damage from erosion, of necessity for drainage in certain areas and other improvements. Messrs. Clyde M. Seibert, District Conservationist, and S. Burkett Johnson, Soil Scientist, of the Watsonville Office of the Soil Conservation Service, United States Department of Agriculture have been associated with development of land uses in several areas in the basin in recent years. Mr. Johnson, under the direction of Mr. Seibert submitted the following supplemental information on soils in the Salinas Basin:

"Soils in the irrigated section of the Salinas Valley occur in two well-defined areas. These include bottom lands next to the river and terraces and fans along the sides of the valley. The areas lying above the bottom land are locally called bench lands. About half the irrigated lands occur in the bottom and the other half lies on the benches. Soils in the bottom lands along the Salinas River are all deep and permeable. Their textures usually are heavy, such as clays and silty clay loams. Soils next to the river are light in texture and often consist of fine sands and fine sandy loams. Slopes are nearly level and erosion is negligible except for river bank erosion and sand movement on some soils subject to wind-blow next to the river. The river bottom soils are relatively fertile compared to the bench land soils and this is reflected in the intense use of these bottom lands.

"The bench lands include alluvial fans, elevated terraces, and stream bottoms along local creeks. Soils on the bench lands are nearly always gritty and usually have coarse or light textures such as sands and sandy loams. These soils usually occur on gentle slopes and they are often affected by slight erosion. Most of the bench soils are deep and rapidly permeable, but some have dense claypan subsoils that are nearly impermeable. These claypan soils are relatively unimportant from the acreage standpoint as they cover only about 7 per cent of the total irrigated area. Other soils have moderately heavy subsoils, but these are sufficiently permeable to support deep-rooted crops. These soils occur on about 29 per cent of the area under irrigation. Most of the bench land soils are not as fertile as the bottom lands, so farming needs to be less intensive on the benches.

"The quality of the soils in the Salinas Valley is determined in large part by their physical and chemical characteristics. These characters are, in turn, dependent largely upon the source of the soil material. The bench soils were derived from rock materials that occur in the Salinas and Gabilan Mountains, whereas the bottom soils were brought down by the Salinas River. The nearby mountains consist largely of quartz-bearing rocks and the resultant soils are usually coarse and gritty. The Salinas River, on the other hand, has its source in a wider variety of rocks and has brought down fine grained material with a more favorable physical and chemical make up.

"The inherent capacity of these soils for agricultural use is shown by the land-capability classes. Land in the bottom usually is Class I and land on the bench is usually Class I or Class II*. This means that most of the land in the irrigated part of the valley can be farmed intensively without fear of deterioration from erosion. Class II land that is sloping or that is poorly drained has more or less limitations for cropping. All these lands need an adequate program of soil and irrigation management to get continued maximum production.

"Class I land in the river bottom is best suited for crops such as lettuce, spinach, carrots, celery, sugar beets, alfalfa, and beans. Potatoes and carrots are better adapted to the softer, light textured soils along the river, and lettuce and sugar beets do better on the heavier soils. Land on the benches is generally not so well suited for lettuce and sugar beets, but alfalfa and beans produce good yields. Choice of crops on the bottom land is usually a matter of convenience, although a few areas require special crops because of poor drainage or saltiness. Most of the bench land will not stand the intensive cropping that is practiced on the bottom. On the benches the soils are usually better suited to the production of one crop each year or to perennial crops such as alfalfa.

"The soils that predominate in the bottom are types of the Salinas and Metz series. On the bench the common soils are types of the Chualar, Greenfield, Hanford, and Bryant series. Most of these soils occur in all the water supply areas that are previously shown on Plate 1. There are wide variations, however, in the relative acreages of these soils in the several areas. These variations in acreage of soil type account, in part, for the differences in water supply areas. This results from natural differences in soil permeability among the various soil types. The natural permeability of these soils may be greatly modified by farming methods. For example: Working the soil while it is wet almost always decreases the permeability of the soil. On the other hand, using green manure crops and soil amendments will make hard soils more porous. Also, subsoiling chiseling helps to loosen up the deeper parts of the soil.

"Following are brief discussions of the natural physical soil conditions that are peculiar to each of the water supply areas shown on Plate 1 hereof:

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* Most large areas include all the land-capability classes. These are numbered from I to VIII, depending upon the intensity with which the land can be used. Classes I to IV include land that is suitable for varying degrees of cultivation; V to VII are suitable for grazing use; and VIII is unsuited for agricultural use. The classes are mostly based on slope and degree of erosion. Class III land is usually too steep for successful irrigation.

(1) Pressure Area

"Soils in this area are generally deep, uniform and naturally fertile. About 78 per cent of the area consists of deep, uniform, permeable soils; nine per cent has soils with moderately compact subsoils; and 13 per cent has shallow, slowly permeable claypans. The dominant soils are heavy-textured types of the Salinas and Metz series. These soils occur in the river bottom, and occupy 40 per cent of the area. Light and medium-textured types of these series make up 33 per cent more. The remainder of the soils occur on the bench land and are types of Chualar, Greenfield and Bryant series. Most of the bottom land soils are underlain by a perched water table which occurs at depths ranging from two to ten feet. This water table is generally deep enough to allow normal growth of most truck crops, but drainage problems become more acute as the tide lands are approached. Some of these areas near Monterey Bay have soils that are salty enough to deter the growing of lettuce and other salt-sensitive crops. The water table creates a soil condition that is best adapted to growing the more shallow rooted crops. Lettuce, carrots, spinach and most other truck crops are suitable for these salt-free soils. The saltier soils in the lowest part of the Pressure Area are best adapted to artichokes and broccoli.

"In 1944 farmers in the Pressure Area favored lettuce, which was grown on about 39 per cent of the area. Next were miscellaneous truck crops which covered 18 per cent. Another 18 per cent was devoted to beans, 7 per cent to sugar beets and only 4 per cent to alfalfa.

"Parts of the bench land in this area are subject to erosion which results from overflow of creeks or from irrigating in excessively long runs. Shorter irrigation runs on gentler slopes help to prevent irrigation erosion and permit more economical use of water. Erosion in the bottom lands is confined to land endangered by riverbank erosion, and to small areas subject to wind erosion.

(2) East Side Area

"This area lies entirely on the bench land and all its soils have light or medium textures. About 22 per cent of the soils are deep, uniform, and permeable. Approximately 49 per cent of the soils have moderately compact subsoils, and 29 per cent have dense claypans. The most extensive soils are light-textured types of Chualar, Greenfield, Hanford, and Bryant series. The soils are deep and permeable excepting those with claypan subsoils. In general, the Hanford and Greenfield soils occur near creeks, and Chualar and Bryant soils occupy the benches between drainages. The soils of the East Side Area are generally somewhat less fertile than soils on the river bottom. They are best adapted to tomatoes, beans, peas and other deep rooted crops that do not require frequent irrigation. These lands cannot support the intensive farming commonly followed on the bottoms.

"In 1944 farmers here grew more beans than any other crop. About 47 per cent of the land was used for beans, 13 per cent for alfalfa, 13 per cent for lettuce and about 10 per cent each for guayule and truck crops.

"Most of the East Side is more or less sloping and irrigation erosion is likely to occur where runs are too long. Short runs on these relatively porous soils permit more economical use of water as well as protecting the land against erosion.

(3) Forebay Area

"Soils in this area have, on the average, slightly coarser textures than those in the Pressure Area. This difference in soil texture probably does not account for much difference in water use between these two areas. Low rainfall, less fog, and more wind no doubt have more effect. About 72 per cent of the soils in the Forebay Area are deep, uniform and permeable. Nineteen per cent of the soils have moderate subsoil compaction, and 9 per cent have claypans. Dominant soils are heavy types of Salinas and Metz series. These occur on about 32 per cent of the area. Light and medium-textured members of these series account for 12 per cent of the area. Greenfield soils occur on 27 per cent of the area and the remainder consists of types of Chualar and Bryant series. Most of the soils are deep, well-drained, and moderately to highly fertile. They are suitable for growing a wide variety of crops. The claypan soils are, of course, adapted only to shallow rooted crops.

"In 1944 the largest acreage of crops was about equally divided between truck crops, alfalfa, and beans. Each was grown on about 22 per cent of the area. Guayule covered 13 per cent, lettuce was grown on 11 per cent, and sugar beets on 7 per cent of the Forebay Area.

"About half of this area is in the bench land and many of the soils occur on slopes that are subject to erosion. Fields need to be laid out with short runs on gentle slopes to prevent erosion and excessive leaching of the soil. Many of these fields need to be protected from damage by overflowing creeks.

(4) Arroyo Seco Cone

"This is another area having a large percentage of light-textured soils. About 85 per cent are deep, uniform and permeable. Twelve per cent have moderately developed subsoils and only three per cent have claypans. The most extensive soils include coarse, light and medium textures of Greenfield, Hanford and Metz series. Smaller areas of Rincon, Chualar, and Salinas soils also occur. These light-textured soils are best suited for growing deep rooted crops that require well drained soils.

"In 1944 beans were grown on 57 per cent of the land and alfalfa on 21 per cent. Truck crops covered 8 per cent and lettuces only 3 per cent.

"The coarse textures of the soils in the Arroyo Seco Cone and their rapid permeabilities may lead to excessive use of irrigation water. This is especially true where shallow rooted crops are irrigated with long runs on land that has not been carefully leveled. Most of the land is on the sloping benches and there is much danger of irrigation erosion and erosion caused by winter runoff on fields that have been cultivated up-and-down the slope. Irrigation of elevated terraces may cause severe erosion where tail water pours over terrace escarpments.

(5) Upper Valley Area

"Soils in the Upper Valley are about equally divided between bench and bottom land. About 57 per cent of the soils are deep, uniform and permeable, and about 43 per cent have moderately developed subsoils. The soils are mainly medium and heavy textured. Medium textures of Salinas, Metz and Lockwood series account for 52 per cent of the soils in the area. Heavy textured types of the Salinas and Metz series occur in the river bottom and cover 28 per cent of the area. The Lockwood soils occur on the bench land. The soils of the Upper Valley are

deep, well-drained, and moderately to highly fertile. A wide variety of crops are adapted to these soil conditions.

"In 1944 sugar beets were grown on 45 per cent of the area, and beans on about 29 per cent. Alfalfa was grown on 9 per cent of the area and 7 per cent was devoted to truck crops.

"Erosion in the area is relatively slight except along the river where there is much danger of riverbank erosion."

CHAPTER IV

INFLOW AND OUTFLOW

Continuous records of runoff from the watersheds that normally supply approximately 75 per cent of the surface inflow to the alluvial fill in the Salinas Basin are available during the past six years. This runoff is measured at the following four stations:

Station	Watershed Area Square Miles
Salinas River at Paso Robles	389
Nacimiento River near San Miguel	343
San Antonio River near Pleyto	283
Arroyo Seco near Soledad	231

The above watersheds embrace less than one-third of the total area tributary to the alluvium of the main valley floor. Continuous records of runoff are available on the Arroyo Seco since 1901 and on the San Antonio since 1929.

Records of runoff were obtained on Estrella Creek during the seasonal years 1939-40 and 1940-41, and on San Lorenzo Creek for three seasonal years, 1939-40 to 1941-42, inclusive. Records of runoff are available for one or more years on a number of lesser tributaries. The measuring stations are maintained by cooperative arrangement between the Division of Water Resources and the Water Resources Branch of the United States Geological Survey.

The runoff from foothill areas directly tributary to the valley floor and other minor sources of surface water in the Salinas Basin including the runoff emanating from precipitation directly on the valley floor has never been measured. The total surface outflow from the basin by way of the Salinas River, except Toro Creek, the foothills north of Toro Creek, and Vierra Lake drainage has been measured continuously since 1929 at the Hilltown Bridge below Spreckels. The total surface outflow from the basin via Tembladero Slough has been estimated from frequent observations by the Division of Water Resources during the seasonal years 1931-32 and 1944-45.

The total annual runoff reaching the alluvial fill below San Ardo has heretofore been estimated for the period 1901 to 1932 and tabulated in the 1933 report by the Division of Water Resources. For purposes of hydrologic analyses hereinafter set forth, the past 16-year period only has been used, i.e., from 1929-30 to 1944-45, inclusive. This 16-year period is used as a base because the average flow of the Arroyo Seco for the period is close to the mean of the long time record. The discharge of the Arroyo Seco has been used as a guide stream in supplying a runoff index to reproduce the records for the unmeasured seasons of partially measured tributaries. Further reasons for using this period are that within it the hydreulic data on inflow, outflow and ground waters are more complete and the current problems have arisen within that time.

The average precipitation, at Salinas for the 44 seasonal years of discharge records on the Arroyo Seco from 1901-02 to 1944-45, inclusive, was 13.89 inches as compared with a long time 72-year mean of 13.90 inches. The average seasonal runoff of the Arroyo Seco for the 44-year period was 130,000 acre-feet. The average runoff of the Arroyo Seco for the 16-year base period from 1929-30 to 1944-45, inclusive, was 128,700 acre-feet, whereas the average seasonal

precipitation at Salinas for this period was 14.92 inches.

Restoration of 16-Year Record

The only stream with a long period of measurement in the Salinas Basin is the Arroyo Seco. The only precipitation station in the basin with a continuous record over the same period of time is at Salinas. As heretofore set forth the average precipitation at Salinas during the 44-year period of runoff records on the Arroyo Seco does not differ materially from the 72-year mean. The average annual runoff of the Arroyo Seco of 130,000 acre-feet during the 44-year period is assumed as equal to the long time mean. The runoff index of watersheds tributary to the alluvial fill in the basin is taken from the Arroyo Seco record. The runoff index is defined as the relationship between the runoff any one year and the mean runoff expressed as a percentage. A summary of precipitation at Salinas and runoff of the Arroyo Seco follows:

Period	Length of Period	Average Precipitation at Salinas-Inches	Average Runoff Arroyo Seco Acre-feet	Runoff Index Per Cent
1901-1945	44 years	13.86	130,000	100
1929-1945	16 years	14.92	128,700	99

The runoff of tributary watersheds with short periods of measurement has been deduced by comparison of these streams with the Arroyo Seco. The discharge of every measured stream was plotted for each year of its record against each corresponding year of discharge of the Arroyo Seco. The seven named unbroken lines on Plate 2 show the runoff curves obtained in this manner. The curves of the Salinas River at Paso Robles and Estrella Creek have been used to reproduce the runoff of corresponding analagous unmeasured streams having similar precipitation, runoff and other watershed characteristics as follows:

(1) The curve of the Salinas River at Paso Robles was used for San Marcos Creek and that portion of the San Antonio River watershed below Pleyto.

(2) The curve of Estrella Creek was used for east side streams from McCoy Canyon to Shirttail Canyon, inclusive, San Carlos to Pinolito Canyon, inclusive, Sweetwater Creek to Redwood Canyon, inclusive, Deadman's Gulch to Hare Canyon, inclusive, Mahoney Canyon, Lowes Canyon, and all east side foothill areas directly tributary to the valley floor.

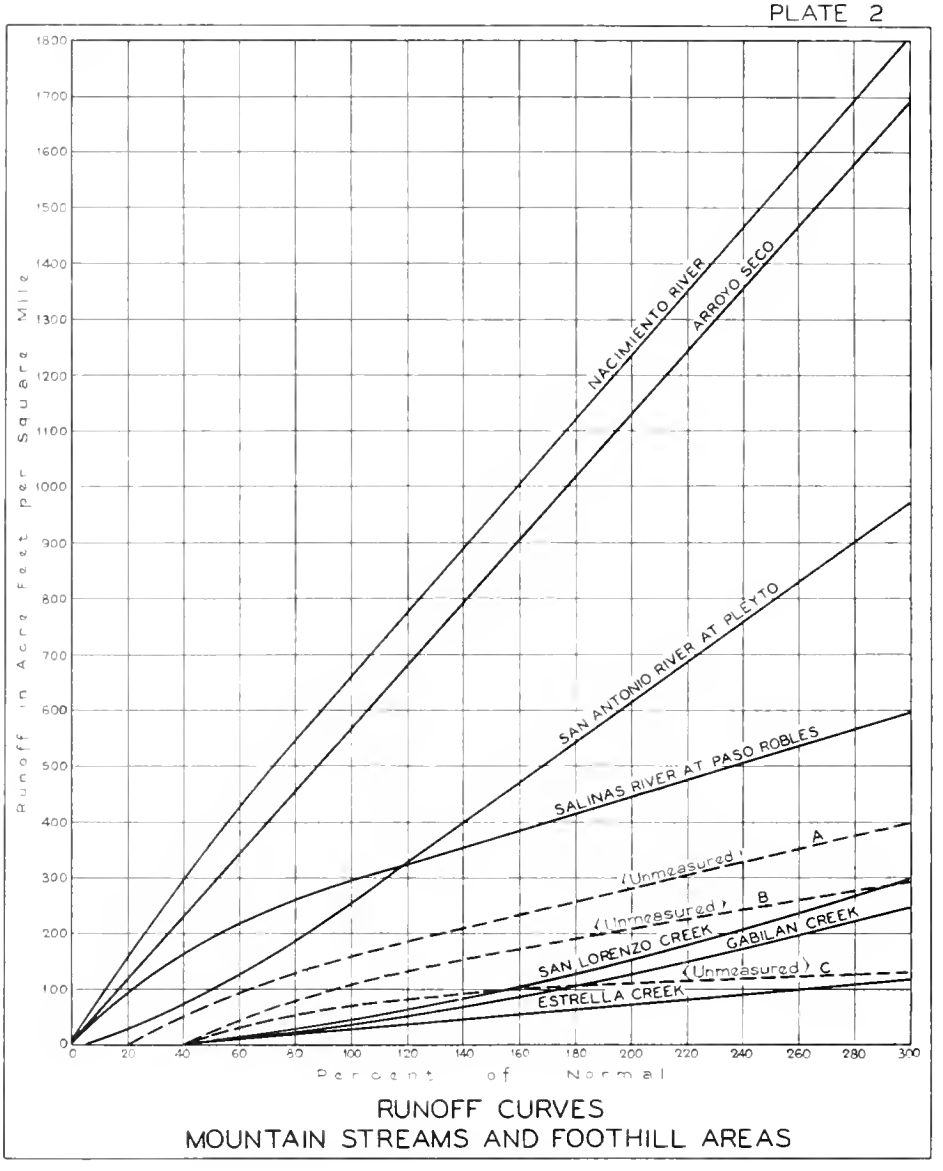
The three intermediate curves designated on Plate 2 as A, B, and C are based on estimated efficiencies of minor watersheds that it is thought will normally range between the values of the Salinas River at Paso Robles and Estrella Creek. These curves have respectively been used to reproduce the runoffs of the following streams:

Curve A was used for west side streams from Garrissee Gulch to Reliz Creek, inclusive, and the unnamed mountain area between the watersheds of Arroyo Seco and Toro Creek. Curve B was used for Toro Creek and all unmeasured west side foothill areas directly tributary to the valley floor.

Curve C was used for Chalone Creek, Pancho Rico Creek, Indian Valley Creek, Vineyard Canyon, and Huerhuero Creek.

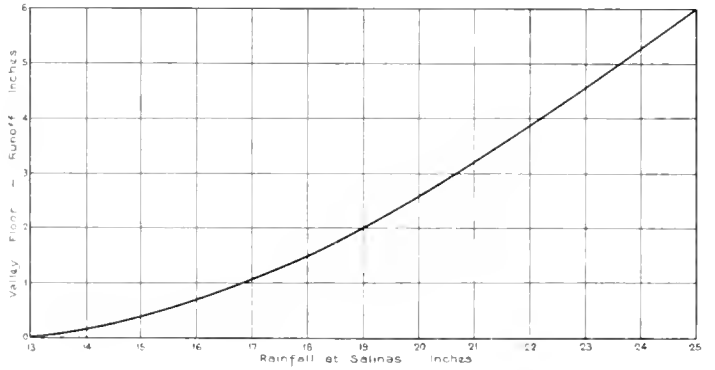
The runoff tributary to the alluvial fill in the Salinas Basin for the three years 1929-30 to 1931-32, inclusive, has been taken from the supporting data studies of the 1933

PLATE 2



RUNOFF CURVES
MOUNTAIN STREAMS AND FOOTHILL AREAS

PLATE 3



RAINFALL – RUNOFF CURVE
PRESSURE AND EAST SIDE AREAS

report of the Division of Water Resources. The records for the period 1932-33 to 1944-45 have been restored in the manner above set forth. The runoff from the valley floor tributary to Tembladero Slough and to the Salinas River has been determined for the entire 16-year period from the curve on Plate 3, as hereafter explained. A tabulation of all measured and estimated runoff during the 16-year period from the Salinas River stream system is set forth in Table 1 in Appendix A at the end of the report. A summary of estimated average inflow during the 16-year base period to the alluvial fill segregated by source of information and authority follows:

Watersheds Embraced	Drainage Area Square Miles	16-year Average Acre-feet	Per Cent of Total Runoff
4 mountain streams measured for 6 years or longer by U.S.G.S. (not subject to much personal equation)	1,246	527,000	75
6 mountain streams measured from 1 to 3 years by U.S.G.S. and State (largely an estimate)	1,295	49,000	7
23 hill areas and east side foothills taken from analagous runoff curves (an estimate)	538	46,000	7
20 hill areas and west side foothills taken from estimated runoff curves A, B, & C (an estimate)	871	79,000	11
Totals	3,950	701,000	100

Precipitation on Alluvial Fill

Precipitation directly on the valley floor in the Salinas Basin is another important source of water supply for the water-consuming cultural classifications on the alluvial fill. The valley floor has been divided into three areas for determination of the total precipitation thereon. The north area embraces all of the Pressure and East Side Areas, the central area includes the Forebay Area and Arroyo Seco Cone, and the south covers the Upper Valley Area. The mean annual precipitation on the valley floor varies from 13.90 inches at Salinas, to 9.12 inches at Soledad and 10.67 inches at King City.

The mean average precipitation over the Pressure and East Side Areas is assumed to be 13 inches, that over the Forebay Area and Arroyo Seco Cone to be 9 inches, and 10 inches in the Upper Valley Area. The estimated 16-year base period average and mean average precipitation over the alluvial fill in the basin is shown in the following table:

Area	Acreage	Average Precipitation Mean Inches	Mean Acre-feet	16-year Period Inches	16-year Period Acre-feet
Pressure and East Side	117,457	13	127,000	14	137,000
Forebay and Arroyo Seco	62,488	9	47,000	9.6	50,000
Upper Valley	59,073	10	49,000	10.7	52,000
Total	239,018	11.2	223,000	12	239,000

The precipitation at Salinas has been used as an index for determination of the average annual precipitation on the alluvium in the Salinas Basin each year during the 16-year period from 1929-30 to 1944-45, inclusive. The average for the 16-year period is calculated to be 239,000 acre-feet. The calculated average annual precipitation during the 16-yeer period on the valley floor has been included in the tabulation of surface water supply hereinafter submitted in Table 1 of Appendix A.

The precipitation over the valley floor probably is largely consumed through evaporation and plant transpiration in years of normal precipitation with the exception of the area in the vicinity of Castroville. The unconsumed portion of the precipitation in this area largely goes to surface runoff due to the high perched water table. There is no contribution to ground water in the commercial zone of pumping generally over the Pressure Area, at any time, due to an impervious blue clay stratum between the sub-soil and the water-bearing formations, with the exception of a limited area in the vicinity of Quail Creek. Due to the high perched water table, the unconsumed portion of precipitation over the Pressure Area finds its way to the natural channels and drainage canals and contributes to surface outflow. Contribution to ground water direct from rainfall is believed to be a factor of some importance in the wetter years in the free ground water areas in the basin.

Lateral Percolation from Hills

The soil mantle on the hills adjoining the valley floor in the Salinas Basin, other than as hereafter set forth, appears to be too fine in texture to permit an appreciable contribution to the water crop reaching the valley floor by way of lateral percolation.

(1) East of the Forebay Area, the deep soil mantle in the hills adjacent thereto between Soledad and King City has a sandy porous texture. There may be appreciable lateral percolation from these slopes to the alluvium in the basin following very wet years. The soil mantle on the hills in this area has a high concentration of solubles. The increase in solubles in the ground water along the easterly fringe of the alluvium in this area, following the wet year of 1941, indicates some lateral percolation as is hereafter discussed in Chapter VII. The hills embrace the most arid portion of the watersheds tributary to the valley floor and there is probably no rainfall penetration below the root zone of the native vegetation except in very wet years. The average contribution over the 16-year base period from this source to the total water crop reaching the valley floor is believed to be small.

(2) The Neponset Sand Ridge on the west side of the valley floor immediately south of the Monterey Branch Railroad lies in a moderately heavy rainfall belt. There is no surface runoff from this ridge which has a sparse cover of native vegetation. The contours of the pressure surface in the vicinity of Neponset indicate the existence there of a small lateral forebay to the Pressure Area. The piezometric influence extended for a distance of about two miles into the Pressure Area along the Monterey Branch Railroad during the early part of the 1945 irrigation season, but had receded to about one-half mile at the end of the season. The low amount of solubles in the sand ridge is appreciably reflected in the better quality of ground water prevailing in the Pressure Area immediately northeast of Neponset. The ridge in the contours of the pressure surface in this vicinity has apparently served to deflect marine intrusion,

as is hereafter explained in Chapter VII. The average contribution over the 16-year base period from this source to the total water crop reaching the valley floor, although locally important, is believed to be comparatively slight, because of the small size of the area.

(3) Marine Intrusion is possible when the elevation of the pressure surface in the Pressure Area near the shore of the Monterey Bay is below mean sea level. Below sea level elevations prevailed in this area for a period of approximately 27 weeks in 1945. As hereinafter discussed in Chapter VI the ground water inflow from the bay to the water-bearing formations in the alluvial fill in 1945 has been calculated to be about 12,000 acre-feet. The average annual inflow from this source during the 16-year base period probably did not exceed half that in 1945 and is estimated to be in the order of 6,000 acre-feet.

Combined Inflow to Alluvium

All of the above mentioned sources of water, when combined, give a measure of the total inflow to the valley floor in the Salinas Basin. There are no importations to the basin. A summary of the estimated annual water crop during the 16-year base period follows:

	Inflow in Acre-feet				
Year	Surface Tributaries	Precipitation on Alluvium	Marine Intrusion	Lateral Percolation	Total
1944-45	519,000	214,000	12,000	Slight	745,000
1943-44	459,000	220,000	11,000	Slight	690,000
1942-43	917,000	234,000	10,000	Slight	1,161,000
1941-42	840,000	289,000	8,000	Appreciable	1,139,000
1940-41	2,109,000	400,000	0	Appreciable	2,515,000
1939-40	889,000	300,000	8,000	Slight	1,197,000
1938-39	132,000	174,000	10,000	Slight	316,000
1937-38	1,691,000	299,000	0	Slight	1,990,000
1936-37	812,000	308,000	3,000	Slight	1,123,000
1935-36	666,000	224,000	4,000	Slight	894,000
1934-35	515,000	277,000	5,000	Slight	797,000
1933-34	427,000	121,000	6,000	Slight	554,000
1932-33	107,000	152,000	7,000	Slight	261,000
1931-32	868,000	280,000	0	Slight	1,148,000
1930-31	46,000	142,000	7,000	Slight	195,000
1929-30	213,000	195,000	5,000	Slight	413,000
16-year Average	701,000	239,000	6,000	Small	946,000

Salinas River Outflow

Continuous records of discharge of the Salinas River at the Hilltown Bridge near Spreckels are available throughout the 16-year base period under consideration. Substantially the entire flow of the river at this point is outflow to Monterey Bay, because of an impervious stratum between the channel and the water-bearing aquifers. Approximately 95 per cent of the average total surface outflow from the Salinas Basin flows past the measuring station. The average annual discharge during the 16-year period from 1929-30 to 1944-45, inclusive, has

been 476,500 acre-feet.

Two of the tributary watersheds above the valley flow discharge directly into the Salinas River below the Hilltown Bridge. These are Toro Creek and the foothills between Toro Creek and the Neponset Sand Ridge. It is believed there is but little retention in the alluvium from these sources, because a large portion of their respective deltas are within the artesian belt in the Pressure Area. It is assumed in the analysis herein that seven-eighths of the total inflow from these sources to the valley floor is disposed of as surface outflow by way of the Salinas River. The average annual inflow from these sources during the 16-year period has hereinbefore been estimated to be 6,800 acre-feet. The average annual outflow is estimated at 6,000 acre-feet.

Waste from East Side Area

The watersheds tributary to the East Side Area have been insufficiently productive of runoff in 11 out of the past 16 years to cause surface outflow into the Pressure Area. The surface outflow from the East Side Area is tributary either to Alisal Slough or to Espinosa Slough, which both flow into Tembladero Slough. The East Side Area tributaries produced waste to Tembladero Slough in 1932, 1936, 1938, 1940 and 1941. It is assumed that this waste occurred only at times when storms were of sufficient magnitude to cause discharges in the Salinas River near Spreckels in excess of 9,000 cubic feet per second for more than four days. Such storms have occurred during the 16-year base period as follows:

Year	Period of Time (both dates inclusive)
1931	December 26 to 30
1936	February 14 to 25
1938	February 10 to 17; and March 2 to 16
1940	February 27 to March 3
1941	February 9 to 19; March 1 to 8; and March 31 to April 8.

The waste from tributaries to the East Side Area during the above periods of time has been estimated from the intensity and duration of the storms and from incomplete information on percolation, as hereinafter set forth in Chapter V as follows:

Seasonal Year	Outflow in Acre-feet
1931-32	700
1935-36	500
1937-38	7,000
1939-40	2,000
1940-41	10,000
16-year Average	1,200

Outflow from Precipitation on Alluvium

In the method of analysis herein used, it is necessary to estimate the runoff from that portion of the valley floor tributary to Tembladero Slough and to the Salinas River below the Hilltown Bridge near Spreckels. All runoff from the valley floor tributary to the Salinas River above the Hilltown Bridge is included in the flow of the river measured at that point

since 1929. The runoff from the valley floor tributary to Tembladero Slough and to the Salinas River below the Hilltown Bridge has been estimated from the rainfall-runoff relationship shown on Plate 3. This curve is based on estimates by the Division of Water Resources of about 1.45 inch from 13.35 inches precipitation at Salinas in the seasonal year 1944-45 and about 1.45 inches runoff from 17.47 inches precipitation on the valley floor when the annual precipitation at Salinas was less than 13 inches. The area of the alluvium tributary to Salinas River below the Hilltown Bridge and Tembladero Slough is approximately 125 square miles.

The precipitation at Salinas was less than 13 inches in 1929-30, 1930-31, 1932-33, 1933-34 and 1938-39. It is assumed there was no outflow from precipitation on the valley floor during these five seasonal years. The estimated outflow for the remaining 11 years of the 16-year base period follows:

Seasonal Year	Precipitation at Salinas-Inches	Outflow from Precipitation-Acre-feet
1944-45	13.35	200
1943-44	13.71	600
1942-43	14.63	2,000
1941-42	18.01	10,000
1940-41	25.04	40,000
1939-40	18.62	12,000
1937-38	18.52	12,000
1936-37	19.21	14,000
1935-36	13.96	1,000
1934-35	17.29	8,000
1931-32	17.47	8,000
	Average 16-year base period	7,000

Surface Outflow Drainage from Irrigation

Any surface drainage from irrigation water that reaches the Salinas River above the Hilltown Bridge is included in the surface outflow measured at that point. There are only occasional instances of surface outflow of the unconsumed portion of irrigation water from free water table areas in the Salinas Basin. The difference between combined extractions and the amount of water represented in "efficiency of irrigation" largely returns to the pumping zone, except in the Pressure Area. "Efficiency of irrigation", as used herein, is defined as the percentage of irrigation water applied that can be accounted for as soil-moisture increase in the portion of the soil occupied by the principal rooting zone of crops.

A large portion of the unconsumed irrigation water in the Pressure Area returns to sloughs, drainage ditches, and the Salinas River and becomes surface outflow. A small portion has returned to the 180-foot aquifer in recent years through collapsed casings in unplugged abandoned wells and possibly natural perforations in the impervious stratum overlying the aquifer as evidenced by limited areas of contamination from perched water in the vicinity of Salinas. Estimates of the irrigation return water reaching Tembladero Slough and the Salinas River below the Hilltown Bridge as outflow during 1944 and 1945 have been made from frequent observations. The change in ground water storage in the perched water zone in the Pressure

Area was small during the course of the investigation, the range in elevation of the perched water table between the commencement and close of the irrigation season in 1945 being about one-half foot. The increment in perched water storage during the irrigation seasons of 1944 and 1945 continued to cause return flow after the close of the seasons until the results were confused by the winter rains. The return flow from irrigation in the Pressure Area which includes the Salinas sewage disposal, not included in the river measurements at the Hilltown Bridge, was estimated to be 16,000 acre-feet in 1944 and 17,000 acre-feet in 1945.

The irrigation practices in the Pressure Area at the beginning of the 16-year base period, as set forth in detail in the supporting data of the 1933 report by the Division of Water Resources, have not changed materially from the current practices hereinafter described in Appendix C. It is assumed that the irrigation return from the area over the 16-year period has varied directly with the acreage irrigated.

(1) The acreage irrigated during the 16-year period has been estimated from cultural surveys by the Division of Water Resources in 1931, 1932, 1944, and 1945, from records of electric power consumption together with precipitation records and from information on crop acres supplied by Mr. A. A. Tavernetti, Monterey County Farm Advisor. The ratio of power consumption to irrigated acreage increases in dry years. The records of electric power consumption includes that used for agricultural purposes on the Monterey Peninsula with that in the Salinas Basin in Monterey County. The electric energy used on the Monterey Peninsula is approximately two per cent of the total. Energy used for commercial and municipal purposes is not included. The acreage irrigated from diesel and gas installations in the Salinas Basin largely offsets the agricultural power consumption on the peninsula. The acreages irrigated in 1930, 1931 and 1932 are taken as those determined by the Division of Water Resources in the prior investigation. A summary of the electric power consumption, seasonal precipitation at Salinas and irrigated acreage follows:

Year	Power Consumption Millions of KWH	Precipitation at Salinas-Inches	Irrigated Acreage	
			Free Water Table	Blue Clay Zone
1930	36.5	12.11	71,000	34,000
1931	44.2	8.85	74,600*	35,000*
1932	34.5	17.47	67,800*	30,000*
1933	36.5	9.52	61,000	30,000
1934	40.0	7.58	59,000	29,000
1935	34.7	17.29	68,000	30,000
1936	40.5	13.96	65,000	30,000
1937	41.1	19.21	70,000	35,000
1938	38.7	18.52	68,000	33,000
1939	50.6	10.83	74,000	36,000
1940	45.6	18.62	74,000	38,000
1941	39.6	25.04	74,000	38,000
1942	40.1	18.01	73,000	37,000
1943	48.1	14.63	80,000	40,000
1944	----	13.71	80,400*	45,000*
1945	----	13.35	80,700*	46,000*
Average		14.92	71,300	35,400

* Surveyed by Division of Water Resources

(2) Variations in return flow from sewage disposal and from irrigation to Tembladero Slough and to the Salinas River below the Hilltown Bridge have been estimated by comparison of observed discharges in 1944 and 1945 with estimated irrigated acreages in the blue clay zone in the Pressure Area. The estimated annual return flow, that is disposed of as an outflow, is set

forth in the following tabulation:

Seasonal Year	Irrigated Acreage Blue Clay Zone	Estimated Outflow Acre-feet
1929-30	34,000	12,000
1930-31	35,000	13,000
1931-32	30,000	11,000
1932-33	30,000	11,000
1933-34	29,000	10,000
1934-35	30,000	11,000
1935-36	30,000	11,000
1936-37	35,000	13,000
1937-38	33,000	12,000
1938-39	36,000	13,000
1939-40	38,000	14,000
1940-41	38,000	14,000
1941-42	37,000	13,000
1942-43	40,000	14,000
1943-44	45,000	16,000
1944-45	46,000	17,000
Average	35,400	13,000

Exportations

The only exportation of water from the Salinas Basin in Monterey County is that from the Castroville area to the Moss Landing area for industrial use since late in 1942. This water is largely discharged into Monterey Bay by way of Moro Cojo Slough. This exportation has been continuous during the past three years at a rate of about 1200 gallons per minute, which is equivalent to approximately 2,000 acre-feet per annum. The average annual exportation during the 16-year period has been less than 400 acre-feet.

The water exported from the headwaters of the Salinas River to Camp San Luis Obispo and the City of San Luis Obispo, since early in 1942, has not been included in the water supply tributary to the alluvium in the Salinas Basin.

Ground Water Outflow

The ground water outflow through the 180-foot aquifer in the Pressure Area to the bay during the seasonal year 1944-45 is hereafter calculated in Chapter IV to be about 19,000 acre-feet. This occurred during the period of about 20 weeks of the winter season. The ground water outflow was materially greater in each of the seasonal years 1931-32, 1937-38, and 1940-41, when the elevation of the pressure surface remained above sea level throughout the Pressure Area during longer periods of time. The rate of movement of the ground water will vary directly with the hydraulic gradient of the pressure surface. The range in the maximum rate of ground water outflow through the 180-foot aquifer during the 16-year period probably has not exceeded about six per cent, because this is the range in the maximum annual slope of the pressure surface. The annual variation in volume of outflow through the aquifer is largely governed by the length of the season when irrigation is unimportant. During the greater part of the irrigation season in 13 years of the 16-year period there has probably been either marine intrusion or no movement of water in the 180-foot aquifer near the shore line of the bay.

There has probably been some ground water outflow to the bay through the 400-foot aquifer continuously during the 16-year period. This has decreased during the irrigation season in recent years, due to resort to extractions therefrom. The first well near the bay shore in the 400-foot aquifer was drilled in 1945. The elevation of the pressure surface in September 1945, was about 2.5 feet above mean sea level. A total of only 37 wells in the 400-foot aquifer

does not provide information comparable to that on the 180-foot aquifer. The estimated outflow from the 400-foot aquifer and other water-bearing formations, if any, in addition to the 180-foot aquifer and perched water zone has hereafter been computed as a differential in 1944-45 to be 8,000 acre-feet. Due to little or no draft on the deeper aquifer prior to 1937, the average annual outflow during the 16-year period was probably greater than in 1944-45 by a substantial amount. The average has been arbitrarily assumed to be in the order of 10,000 acre-feet.

Perched water outflow directly to the bay is necessarily small because of the small area susceptible to such direct drainage. This is hereafter computed as somewhat less than 600 acre-feet in 1944-45. There is probably no substantial difference between the average for the 16-year period and that in 1944-45.

The foregoing discussion leads to a conclusion that the average annual ground water outflow during the 16-year period was in the order of 30,000 acre-feet.

Combined Outflow from Alluvium

All of the above mentioned means of disposal of water, when combined, give a measure of the total outflow from the valley floor in the Salinas Basin, exclusive of consumptive uses and changes in storage. The single item of measured surface outflow of the Salinas River near Spreckels makes up approximately 90 per cent of the total. A summary of combined outflow follows:

	Outflow in Thousand Acre-feet							
Year	Measured Salinas River	Toro Creek and N.W. Hills	East Side Area	Rainfall below Spreckels	Irrigation Return	Export	Ground Water	Total
1944-45	312	4	0	0.2	17	2	27	362
1943-44	290	3	0	.6	16	2	28	340
1942-43	745	6	0	2	14	2	29	798
1941-42	534	8	0	10	13	0	30	595
1940-41	1,765	15	10	40	14	0	38	1,882
1939-40	540	9	2	12	14	0	30	607
1938-39	15	0	0	0	13	0	26	54
1937-38	1,397	13	7	12	12	0	35	1,476
1936-37	614	7	0	14	13	0	32	680
1935-36	384	5	0.5	1	11	0	31	433
1934-35	235	4	0	8	11	0	31	289
1933-34	88	2	0	0	10	0	29	129
1932-33	19	0	0	0	11	0	27	57
1931-32	641	13	1	8	11	0	33	707
1930-31	2	0	0	0	13	0	25	40
1929-30	42	4	0	0	12	0	29	87
Average	476	6	1	7	13	-	30	533

Difference between Inflow and Outflow

The difference between the inflow and outflow each year during the 16-year period is a measure of the annual retention in the alluvial fill. A summary of the annual retention in acre-feet follows:

Year	Total Inflow	Total Outflow	Total Retention
1944-45	745,000	362,000	383,000
1943-44	690,000	340,000	350,000
1942-43	1,161,000	798,000	363,000
1941-42	1,139,000	595,000	544,000
1940-41	2,515,000	1,882,000	633,000
1939-40	1,197,000	607,000	590,000
1938-39	316,000	54,000	262,000
1937-38	1,990,000	1,476,000	514,000
1936-37	1,123,000	680,000	443,000
1935-36	894,000	433,000	461,000
1934-35	797,000	289,000	508,000
1933-34	554,000	129,000	425,000
1932-33	261,000	57,000	204,000
1931-32	1,148,000	707,000	441,000
1930-31	195,000	40,000	155,000
1929-30	413,000	87,000	326,000
Average	946,000	533,000	413,000

The annual retention plus or minus the corresponding annual change in ground water storage is a measure of the total water consumption on the valley floor for that year.

Change in Ground Water Storage

There has been no important change in ground water storage in the alluvial fill of the Salinas Basin during the past 16 years, except in the East Side Area and in the Quail Creek delta of free water table included in the Pressure Area. The aquifers in the artesian belt in the Pressure Area remain saturated at all times. Water elevations in the Upper Valley and Forebay Areas have had a narrow range of fluctuation of about six feet between the low in 1931 and the high in 1941. There are no measurements of record of ground water elevations in the basin during 1929-30. As hereafter set forth in Chapter V, the calculated retention of runoff from tributary watersheds in the Upper Valley and Forebay Areas, excluding the effect of precipitation directly on the areas, in 1929-30 was about 90 per cent of that in 1944-45. This difference in retention reflects the difference in capacity for percolation from the stream channels due to greater consumption in 1944 than in 1929. It is believed that water elevations in the Upper Valley and Forebay Areas were as high prior to the commencement of the irrigation seasons in both 1930 and 1945 as it is possible to obtain from Salinas River percolation. Water elevations were approximately four feet higher in 1941 than in 1945 in the Upper Valley and Forebay Areas due to contribution to ground water directly from rainfall and from lateral tributaries to the valley floor at elevations higher than the river.

(1) The East Side Area and that portion of the Pressure Area overlying free ground water has had a substantial decrease in ground water storage between the dry year of 1931 and 1945. Although no records of ground water elevations are available in this area in 1929-30, it is believed that water levels were slightly higher in 1930 than in 1931. A substantial portion of the irrigation development in the East Side Area has occurred during the last half of the 16-year base period. Cross sections of water elevations in 1931 indicate that all the free water table area now included in the Pressure Area was in the East Side Area at the beginning of the 16-year base period.

There was an average drop in water elevations in all measuring wells in the East Side Area at the end of the 1945 irrigation season of approximately four feet as compared with the fall of 1944. The average net lowering of water elevations between the fall of 1929 and the fall of 1945 is estimated to be about five feet which has largely occurred since 1941.

(2) The Arroyo Seco Cone water elevations in the fall of 1945 were substantially the same as in the fall of 1932. There are no measurements of record in 1929, but comparison of estimated percolation from the Arroyo Seco prior to the 16-year base period and at the end of the period indicate a slight increase in ground water storage during the 16-year period. Comparative estimates of percolation from the Arroyo Seco follow.

Seasonal Year	Percolation in Acre-feet*
1944-45	51,000
1931-32	50,000
1928-29	31,000
Average for 16-year base period	51,000

* Determined by the method described in Chapter V.

Heavier consumption of water in the Arroyo Seco Cone and greater movement of ground water from the cone to the Forebay Area in 1945 than in 1929 will partially offset the difference in percolation. The average annual increase in ground water storage in the cone during the 16-year base period, which is further discussed in Chapter VI, is believed to be small.

(3) Vadose water in transit to the water table probably had no important effect on change in ground water storage between the beginning and end of the 16-year base period. The two years preceding the period and the last two years of the period were all subnormal in precipitation. As hereinafter set forth, there is probably no contribution to ground water in normal or subnormal years directly from rainfall on the alluvial fill. There was an increase of approximately 10,000 acres in irrigated land overlying free water table between the beginning and end of the base period. Approximately half of this increase in irrigated acreage was in areas where depth to water varies from 100 to 200 feet and the remainder from 25 to 100 feet.

A substantial portion of the increase in irrigated acreage overlying free water table during the past 16 years has been in the East Side Area. The estimated amount of water pumped in 1944 for irrigation of approximately 15,000 acres was 33,000 acre-feet of which about 18,000 acre-feet were consumed and the remainder percolated below the root zone. The total return for the year was thus about one acre-foot per acre of irrigated land. If all of the annual return from the 10,000 acres of additional land was in transit at the end of the 16-year period, the amount of additional vadose water would be in the order of 10,000 acre-feet. It is believed that a major portion of the annual return reaches the water table before October 1.

(4) The combined change in ground water storage during the 16-year period is estimated to be a decrease in the order of 30,000 acre-feet, which represents an average annual change of about 2,000 acre-feet. This estimate is based on an average drop in water levels of five feet in the East Side Area and of 10 feet in the free ground water in the Quail Creek section in the Pressure Area, and a specific yield of 13.8 per cent.

Consumptive Uses During 16-Year Period

The average annual retention in the valley floor of the Salinas Basin during the 16-year period plus the average annual decrease in ground water storage is a measure of the average annual consumption of water on the alluvial fill during the period. This method of approach indicates an average annual consumption of 415,000 acre-feet.

A determination of normal unit consumptive uses of water for the various cultural classifications on the alluvial fill in the Salinas Basin has been made by the integration method of Mr. Harry F. Blaney, Senior Irrigation Engineer, Division of Irrigation, United States Department of Agriculture, as hereinafter set forth in Appendix C. This independent method of approach may be used as an approximate check on the average consumption of water during the 16-year period, as determined by the inflow-outflow method, with the following assumptions.

1. That there has been no material change in the native vegetation and miscellaneous cultural classifications during the 16-year period.

2. That the increase in irrigated land during the period has been accompanied by a corresponding decrease in the irrigable land.

3. That the proportions of the respective irrigated cultural areas for the entire period are the same as in the 1944 cultural survey, Table 4 of Appendix A.

4. That the average unit consumptive uses during the period are equal to the normal units, as hereafter defined in Appendix C.

As hereinbefore set forth, the estimated average annual irrigated acreage during the 16-year period is 107,000 acres. The average annual irrigable area devoted to dry-farm and native annual grass has been about 70,400 acres. The average annual consumption of water on the valley floor based on the foregoing assumptions is shown in the following tabulation:

Cultural Group	Average Acreage	Normal Annual Consumptive Use	
		Unit-feet	Acre-feet
Irrigated	107,000	1.93	206,000
Irrigable	70,400	.99	70,000
Native Vegetation	30,400	2.94	89,000
Miscellaneous	31,200	1.59	49,000
Totals	239,000	---	414,000

CHAPTER V

PERCOLATION

Separate percolation studies have been made on streams tributary to the East Side Area and on the Arroyo Seco. Segregation of the percolation from the Arroyo Seco in the Arroyo Seco Cone allows an estimate to be made of the percolation from the Salinas River in the Upper Valley and Forebay Areas as a differential.

East Side Tributaries

The total runoffs of Gabilan Creek, Natividad Creek, Alisal Creek, Quail Creek and Chualar Canyon at the easterly edge of the alluvial fill in the Salinas Basin were obtained for the seasonal year 1944-45 by frequent observations of staff gages installed in each stream. The runoffs of Johnson Canyon and other unmeasured tributaries were estimated from intermittent observations. The combined runoff tributary to the East Side Area in 1944-45 was estimated to be 2750 acre-feet. This runoff was observed to all percolate in the easterly half of the East Side Area.

The flows emanating from the watersheds tributary to the East Side Area are normally inadequate to produce any surface waste from the area. In only five out of the past 16 years has any surface flow carried through the East Side Area into the Pressure Area, which waste has hereinbefore been estimated. With the assumption that evaporation and transpiration losses from the stream channels are negligible during the runoff season in the East Side Area, the percolation from stream flow has been estimated as the difference between inflow and outflow during the past 16 years as follows:

Year	Inflow Acre-feet	Waste Acre-feet	Percolation Acre-feet
1944-45	2,750	0	2,750
1943-44	1,800	0	1,800
1942-43	4,600	0	4,600
1941-42	7,500	0	7,500
1940-41	27,000	10,000	17,000
1939-40	8,800	2,000	6,800
1938-39	0	0	0
1937-38	22,000	7,000	15,000
1936-37	5,900	0	5,900
1935-36	4,000	500	3,500
1934-35	2,000	0	2,000
1933-34	1,200	0	1,200
1932-33	0	0	0
1931-32	13,000	700	12,300
1930-31	0	0	0
1929-30	0	0	0
Average	6,200	1,200	5,000

An approximate check is made on the above average percolation from tributary streams in the East Side Area by comparison with normal consumptive uses obtained by the integration method, as hereafter set forth in Appendix C, in the following tabulation:

Cultural Group	Average Acreage	Normal Consumption Unit-feet	Normal Consumption Acre-feet
Irrigated	10,000	1.86	18,700
Irrigable	23,969	1.10	26,300
Native Vegetation	123*	4.51*	500
Miscellaneous	2,385	1.11	2,500
Totals	36,477	----	48,000

*Swamp only

The estimated average annual [illegible] in the East Side Area [illegible] 40,000 acre-feet during the past 16 years. For the above estimated annual percolation of [illegible] acre-feet furnishes an approximate check on the above estimated annual consumption of [illegible] acre-feet less average annual depletion of ground water storage in the area of [illegible] acre-feet.

Part of the time during the 16-year period, there has probably been ground water outflow from the East Side to the Pressure Area, a part of the time little or no flow, and the remainder of the period the direction of movement has reversed to inflow from the Pressure Area. The foregoing analysis indicates the net effect has probably been an average annual ground water inflow for the period in the order of 1,000 acre-feet.

The normal consumptive use of water in the East Side Area based on acreage irrigated in 1944 is approximately 52,000 acre-feet as determined by the integration method. This indicates a present average annual rate of depletion of ground water storage in the East Side Area of about 7,000 acre-feet.

Arroyo Seco

Continuous records of runoff of the Arroyo Seco at the point where it enters the alluvial fill together with observations of contribution of surface flow to the Salinas River provide the basis for a reliable estimate of the total percolation from the Arroyo Seco Cone during the seasonal year 1944-45. The entire flow in the Arroyo Seco in 329 days of the seasonal year went to percolation and evapo-transpiration. There was surface waste from the cone into the Salinas River during 36 days of the year. Notes on observations of contribution of surface flow from the Arroyo Seco to the Salinas River follow:

> "The Arroyo Seco flowed through to the lower bridge on the night of December 23, 1944 for a few hours but had receded to a point above the bridge the following morning. The mean flow for the day at the head of the cone was 224 cubic feet per second. The flow was approximately 250 cubic feet per second for about three hours at the peak.
>
> "The Arroyo Seco flowed through just to Salinas River for about six hours of the afternoon of December 29, 1944, and receded to above the bridge that night. The mean daily flow at the head of the cone on December 29, was 257 cubic feet per second.
>
> "The Arroyo Seco flowed through in volume to the Salinas River from February 1 to 15, 1945. The flow ceased to reach the river on the afternoon of the 15th and receded to a point above the lower bridge on the 16th. The mean daily flow at the head of the cone on February 15 was 261 cubic feet per second and on the 16th was 236 cubic feet per second. The percolation during the first 15 days of February is estimated at an average rate of 250 cubic feet per second. The entire flow percolated from February 16 to March 12, 1945, both dates inclusive.
>
> "Between March 15 and 21, the contribution of the Arroyo Seco to the river varied from about 350 cubic feet per second on the 15th to zero on the 21st. The mean daily flow on March 21 was 241 cubic feet per second at the head of the cone.
>
> "The Arroyo Seco flowed through to the river continuously between March 23 and April 5. The mean daily flow on April 5, was 251 cubic feet per second. The entire flow of the Arroyo Seco from April 5 to September 30, 1945, percolated with the exception of a small amount of evapo-transpiration under the Clark Canal and in the creek channel.
>
> "Reliz Creek contributed flow to the Arroyo Seco for only three days in 1944-45. The inflow from Reliz Creek was estimated to be in the order of 3,000 acre-feet from February 1 to 3, inclusive."

It is believed that an assumption of a uniform rate of percolation of 250 cubic feet per second from the Arroyo Seco when the flow at the head of the cone is in excess of that quantity will result in but a small error in the amount of total percolation for the year. A varia-

tion of 20 cubic feet per second in the rate of percolation for the 36-day period involved in contribution to the river would result in an error of about three per cent. There is probably no contribution from Reliz Creek when the discharge of the Arroyo Seco is less than 250 cubic feet per second. The same formula has been used in calculation of the estimated annual percolation from the Arroyo Seco in the Arroyo Seco Cone each year during the 16-year base period as follows.

Seasonal Year	Arroyo Seco Discharge at Head of Cone Acre-feet	Retention of Arroyo Seco Flow in Cone in Acre-feet	Per Cent of Total Flow Retained
1944-45	105,000	51,000	48
1943-44	88,640	47,000	53
1942-43	132,700	60,000	45
1941-42	169,200	86,000	51
1940-41	380,200	91,000	24
1939-40	186,600	67,000	36
1938-39	24,100	23,000	95
1937-38	323,700	72,000	22
1936-37	148,500	61,000	41
1935-36	120,600	52,000	43
1934-35	92,150	56,000	61
1933-34	77,400	42,000	54
1932-33	19,500	17,000	87
1931-32	132,000	50,000	38
1930-31	12,200	12,000	98
1929-30	46,800	32,000	68
Average	128,700	51,000	40

It was further noted that the entire outflow from the Arroyo Seco into the Salinas River on February 1, 1945, of approximately 9,000 acre-feet was retained in the Forebay Area above the Gonzales Bridge. The first flow during the seasonal year past Gonzales Bridge occurred on the morning of February 2, 1945.

Salinas River

The entire measured inflow to the alluvial fill in the Salinas Basin from the watersheds south of King City in the amount of approximately 44,000 acre-feet between October 1, 1944 and February 1, 1945, both dates inclusive, was retained in the Upper Valley Area. There was no flow in the river past Metz during the seasonal year until the morning of February 2. There was no flow from unmeasured tributaries prior to February 1. There was percolation from the Salinas River of Arroyo Seco inflow between the mouth of the Arroyo Seco and Gonzales Bridge of about 9,000 acre-feet on February 1, 1945. Direct observations of percolation from the river after February 1, were obscured by the flood flows that occurred.

Measurements made on key wells in the Forebay and Upper Valley Areas at 3-week intervals during the winters of 1944-45 and 1945-46, indicated recovery of ground water elevations to the approximate height possible from river percolation in less than one month after continuous flow from San Ardo to the bay. Percolation continues from the river in these areas as long as there is flow in the river to replace consumptive uses and to replace ground water movement from the Forebay Area into the Pressure Area.

Assuming all precipitation on the valley floor tributary to the Salinas River above Spreckels is retained in the alluvial fill, calculation of the additional retention of inflow from tributary watersheds above Spreckels for the 16-year base period is shown in the following tabulation:

Year	Tributary Inflow above Spreckels	Outflow at Spreckels	Runoff Retention above Spreckels	Runoff Retention in Arroyo Seco Cone	Inflow Retention Forebay and Upper Valley
	Discharges in Thousand Acre-feet				
1944-45	511	312	199	51	148
1943-44	454	290	164	47	117
1942-43	906	745	161	60	101
1941-42	824	534	290	86	204
1940-41	2,064	1,765	299	91	208
1939-40	871	540	331	67	264
1938-39	132	15	117	23	94
1937-38	1,654	1,397	257	72	185
1936-37	798	614	184	61	123
1935-36	656	384	272	52	220
1934-35	509	235	274	56	218
1933-34	423	88	335	42	293
1932-33	107	19	88	17	71
1931-32	840	641	199	50	149
1930-31	46	2	44	12	32
1929-30	206	42	167	32	135
Average	688	477	211	51	160

The average precipitation during the 16-year period on the Forebay and Upper Valley Areas has hereinbefore been estimated to be 84,000 acre-feet. The surface runoff for the period from precipitation on the portions of the Pressure and East Side Areas tributary to the river above Spreckels must be added to obtain the average retention in the Upper Valley and Forebay Areas. Slightly less than one-third of the Pressure and East Side Areas is tributary to the river above Spreckels. The rainfall-runoff relationship shown on Plate 3 indicates an average runoff from precipitation on 59 square miles of valley floor tributary to the river between Spreckels and Gonzales of approximately 3,000 acre-feet during the 16-year period. The average additional retention over and above precipitation in the Upper Valley and Forebay Areas is thus calculated to be about 163,000 acre-feet for the period.

A major portion of the calculated average inflow retention of 163,000 acre-feet must percolate in the Upper Valley Area due to the more limited average capacity for percolation in the Forebay Area. As hereafter set forth, the Forebay Area must have received an average annual ground water inflow from the Arroyo Seco Cone of about 31,000 acre-feet and an undetermined amount from Upper Valley.

Ground Water Movement

There has been no material change in storage in the Arroyo Seco Cone and the Upper Valley and Forebay Areas during the 16-year period. No appreciable change in storage has been possible in the blue clay zone in the Pressure Area. There has been an appreciable change in storage in the free water table portion of the Pressure Area in the Quail Creek delta embracing about 5,000 acres as hereinbefore set forth. The following computations on ground water movement from the various areas also serve as an independent check on average total percolation in the Arroyo Seco Cone, and Upper Valley and Forebay Areas. The calculations are based on the assumption that average unit consumptive uses over the 16-year period were equal to the normal units hereinafter set forth in Appendix C.

(1) The Arroyo Seco Cone average annual percolation during the 16-year period, as above computed, has been approximately 51,000 acre-feet. The average annual precipitation on the cone has previously been estimated as 18,000 acre-feet for the period. The total annual retention on the cone available for consumptive uses and ground water outflow to the Forebay

Area is thus about 69,000 acre-feet for the period. The estimated average annual consumption in the cone based on normal unit consumptive uses is shown in the following tabulation:

Cultural Group	Average Acreage	Normal Consumption Unit-feet	Normal Consumption Acre-feet
Irrigated	13,000	2.12	27,500
Irrigable	3,890	.75	2,900
Native Vegetation	1,627	3.10	5,000
Miscellaneous	3,598	.73	2,600
Totals	22,115	----	38,000

In the absence of any material change in ground water storage, the average annual ground water movement from the Arroyo Seco Cone into the Forebay Area during the 16-year period appears to be approximately 31,000 acre-feet. The total ground water movement from the cone over the 16-year period thus appears to be in the order of a half million acre-feet. The importance of the Arroyo Seco Cone as a natural regulator of the flow of the Arroyo Seco is apparent.

(2) The Upper Valley and Forebay Areas are treated as a unit in so far as ground water movement is concerned due to the absence of delimiting information on percolation. The combined average annual retention from tributary inflow and precipitation directly on the two areas over the 16-year period has previously been estimated as 247,000 acre-feet. The estimated combined average annual consumption in the two areas for the period based on normal unit consumptive uses is set forth in the following tabulation:

Cultural Group	Area	Average Acreage	Normal Consumption Unit-feet	Normal Consumption Acre-feet
Irrigated	Forebay	22,000	2.17	48,000
Irrigable	Forebay	5,818	.75	4,000
Native Vegetation	Forebay	6,371	2.68	17,000
Miscellaneous	Forebay	6,184	1.53	9,000
Irrigated	Upper Valley	21,000	2.13	45,000
Irrigable	Upper Valley	15,097	.83	12,500
Native Vegetation	Upper Valley	13,757	2.48	34,000
Miscellaneous	Upper Valley	9,219	1.88	17,500
Totals	----	99,446	----	187,000

The total retention in the Upper Valley and Forebay Areas plus the ground water inflow from the Arroyo Seco Cone provide an apparent average annual water supply of 278,000 acre-feet available for consumptive uses in the two areas and ground water movement into the Pressure Area. With no material change in ground water storage in the two areas, the apparent average annual ground water movement from the Forebay Area to the Pressure Area during the 16-year period has approximated 91,000 acre-feet. The total ground water movement from the Forebay Area into the Pressure Area over the 16-year period thus appears to be in the order of one and one-half million acre-feet. This quantity of water plus the retention from precipitation and inflow to the Pressure Area must substantially balance the consumptive uses in the Pressure Area plus net ground water outflow to the bay plus surface drainage outflow from irrigation and

exportation therefrom, as later set forth in this chapter.

(3) The Pressure Area net annual ground water outflow over and above marine intrusion and lateral inflow from the Neponset Sand Ridge has previously been estimated at 64,[illegible] acre-feet during the 16-year period. The average annual exportation from the Pressure Area for the period has been about 400 acre-feet as previously set forth and the average annual surface drainage outflow from irrigation in the blue clay zone has been estimated as 13,000 acre-feet. The average percolation from Toro Creek and the foothills north of Toro Creek in the Pressure Area has been estimated as 800 acre-feet for the period.

The estimated average acreage irrigated in the blue clay zone during the 16-year period has previously been estimated to be approximately 35,400 acres. The average irrigated acreage overlying free water table in the Pressure Area is estimated to be about 5,000 acres for the period. The estimated average annual consumption in the Pressure Area for the period based on normal unit consumptive uses is set forth in the following tabulation:

Cultural Group	Average Acreage	Normal Consumption Unit-feet	Acre-feet
Irrigated	40,000	1.69	68,000
Irrigable	22,230	1.10	24,000
Native Vegetation	8,541	3.81	32,000
Miscellaneous	9,809	1.73	17,000
Totals	80,980	----	141,000

The estimated average annual disposition of water in the Pressure Area during the 16-year period follows:

Item	Acre-feet
Consumptive uses	141,000
Ground water outflow	30,000
Irrigation surface drainage outflow	13,000
Runoff from rainfall on alluvium	7,000
Net ground water escape to East Side Area	1,000
Exportation	400
Average annual disposition	192,400

The estimated average annual water supply in the Pressure Area available for the foregoing disposition follows:

Item	Acre-feet
Ground water flow from Forebay Area	91,000
Precipitation on Pressure Area	94,[illegible]00
Retention from Toro Creek and foothills	800
Marine intrusion	6,000
Change in ground water storage (Quail Creek)	400
Average annual supply	192,200

The increased ground water extractions in the Pressure Area have materially increased the current rates of ground water flow thereto from both the Forebay Area and from marine intrusion as compared with the foregoing estimated average flows. A detailed discussion of the ground

water flow to the Pressure in 1945 is hereinafter set forth in Chapter VI.

Sources of Surplus Surface Flow

Approximately 80 per cent of the total surface inflow from watersheds tributary to the East Side Area during the 16-year period has been retained in that area. There was 100 per cent natural regulation of the flows of these streams in 11 of the 16 years. The small average surplus water in these streams occurs so infrequently that consideration of enhancement of the supply through local development in the area is unwarranted.

Approximately 94 per cent of the estimated inflow to the alluvial fill from tributary watersheds in the Salinas Basin, as hereafter set forth in Table 1 of Appendix A, during the 16-year period has occurred in the Arroyo Seco and in the tributaries south of the mouth of the Arroyo Seco. The average annual inflow to the alluvium from the Arroyo Seco and watersheds to the south has been estimated to be 658,000 acre-feet from which there has been an average annual waste to the bay of about 444,000 acre-feet. Any substantial enhancement of the supply of water available for beneficial uses in the Salinas Basin necessarily must involve salvage of a portion of this large surplus. The surplus water in this area was less than 20,000 acre-feet in three dry years during the 16-year period, it being as low as 2,000 acre-feet in 1930-31. Additional water for use in critical dry years obviously is dependent on cyclic storage either in surface reservoirs or underground.

CHAPTER VI

UNDERGROUND HYDROLOGY

Contamination of the water supply by marine intrusion may be the criterion controlling the rate of safe yield in a coastal plain pressure area such as that in the Salinas Basin, where the water-bearing formations have contact with sea water. The study of the underground reservoir of Salinas Valley includes a determination of safe yield and overdraft in the Pressure Area with contamination through marine intrusion as the controlling factor. The study also embraces consideration of alluvium overlying free ground water in the basin to define areas where present draft exceeds the average annual recharge and to ascertain the location and extent of surplus underground storage within the limits of safe yield.

Valley Fill

This discussion of the valley fill is based on observations of ground water behavior and a study of well logs and well driller information. Logs of 420 wells distributed over the valley floor have been identified with the respective well numbers shown on Plates 17 to 21, inclusive, at the end of this report. The well logs have been set forth with the basic data in Bulletin 52A. Several lines of logs plotted along the main axis of the valley and at right angles thereto show the valley fill to be complex with numerous lenses from the side tributaries interspersed within the principal influence of the Salinas River.

(1) Pressure Area

The only consistent strata in the valley fill appear to be two continuous layers of blue clay between Gonzales and Monterey Bay. The blue clay zone appears to average more than 4½ miles in width and abuts the easterly base of the Santa Lucia Range on the westerly edge of the valley floor. There are two aquifers with partially confined waters throughout the blue clay zone. The average depth to near the center of the upper aquifer is about 180 feet and it is referred to herein as the 180-foot aquifer. There is a stratum of impervious blue clay overlying the 180-foot aquifer. Another stratum of blue clay separates the 180-foot aquifer from the deeper water-bearing formation, designated the 400-foot aquifer. There are 660 wells presently operating that are perforated exclusively in the 180-foot aquifer, and 37 that tap only the 400-foot aquifer. The wells perforated in the 180-foot aquifer are generally seated on the blue clay seperating the aquifers. There are only two wells that are known to be perforated in both aquifers. There are also numerous non-operating and domestic wells with negligible draft on the 180-foot aquifer throughout the Pressure Area. The 180-foot aquifer supplies more than 95 per cent of the current total demand for water in the Pressure Area. There have been no drillings in the Pressure Area below the 400-foot aquifer.

The water-bearing gravels and sands in the 180-foot aquifer in 200 well logs show a variation in thickness from 35 to 179 feet with an average of about 100 feet. There is an inadequate number of logs through the 400-foot aquifer to form an estimate of average thickness of this water-bearing formation, but indications are that it may be materially less than the 180-foot aquifer. It is presumed that the water-bearing formations in the Pressure Area terminate at the southeast wall of the ocean canyon in Monterey Bay previously described in Chapter III.

The fountain head of the 400-foot aquifer on the south has not been revealed through well logs. The drillings west of Highway 101 between Gonzales and Soledad have been comparatively shallow due to high yielding wells in this vicinity. The excellent prevailing quality of water in the 400-foot aquifer indicates that it may have as a forebay the Arroyo Seco Cone, rather than the Forebay Area in common with the 180-foot aquifer. The ground water in the Forebay Area now has substantially greater concentration of solubles than the 400-foot aquifer. The amount of solubles in the ground waters of the Forebay Area may be due to recent increases that have not had time to move into the 400-foot aquifer. The 400-foot aquifer extends farther to the east than the 180-foot aquifer between Carr Lake and Santa Rita.

(2) Forebay Area

There is free ground water in unconsolidated alluvium more than 500 feet in depth south of Gonzales along State Highway 101 in the Forebay Area. The gravels, sands and silts since deposition have been in process of change through decomposition from gravel to clay. All shades of material are indicated by the logs. Any stratum may range from coarse open gravel to fine sand, sandy and gravelly clays and clays with varying arrangements in succeeding strata. The clays found in the free ground water areas are yellow or red in color and are in unconnected lenses. The water table in the Forebay Area joins the perched water table overlying the upper stratum of blue clay in the Pressure Area. The movement of water from the Forebay Area to the perched water is comparatively small due to the high clay adobe content of the soil and sub-soil in the Pressure Area.

Heavy producing wells are generally obtained at comparatively shallow depths in the Forebay Area with the exception of the district east of Highway 101 between Gonzales and Soledad. Yields in excess of 200 gallons per minute per foot of drawdown are quite common as shown in Table 2 of Appendix A. The east side of the valley between Gonzales and Soledad is generally served with water by means of booster installations.

(3) East Side Area

There is free ground water throughout the East Side Area adjoining the blue clay zone on the east between Merritt Lake and Gonzales. The overlap in the outwash of deltas of the various streams tributary to the East Side Area is composed of a large percentage of fines and in some instances act as partial ground water barriers. The consolidation of strips of alluvium between Gabilan and Natividad Creeks, and between Gabilan and Santa Rita Creeks is quite marked, neither of which will support pumping draft for irrigation purposes. There are several strips between the alluvial fans to the south, in the East Side Area, where wells of low yield have been drilled. Contours of ground water elevations indicate the main tongues of gravel deposits in several of the East Side Area deltas may be interconnected with the water-bearing formations in the Pressure Area. Logs of two deep wells in the Santa Rita and Alisal areas indicate the valley fill to be more than 900 feet in depth in the East Side Area. Many of the recent drillings in the East Side Area range from 400 to 700 feet in depth.

(4) Arroyo Seco Cone

Heavy strata of boulders and coarse gravel predominate in the fill of the Arroyo Seco Cone to depths of 500 to 700 feet. Moderate layers of coarse sand and reddish yellow clay streaks

are found throughout the drillings. No wells that would supply irrigation draft have been developed in the Relis Creek delta, after several drillings. Depths to water on the bench land on both sides of the Arroyo Seco near the head of the zone are in excess of 200 feet. The elevation of the present streambed of the Arroyo Seco is so low that natural replenishment of ground water in the bench land at shallow depths is not possible.

(5) Upper Valley Area

A shallow stratum of blue clay is generally found in the drillings on both sides of the Salinas River in the Upper Valley Area between the southerly end of the Forebay Area and south of the Coburn Station. The shallow water overlying this blue clay is generally of poor quality probably due in large part to the inflow from the east side watersheds. The deeper water is of good quality. Blue clay and blue sands and gravels below a depth of about 150 feet are found in the southerly portion of the San Lorenzo delta north of San Lucas. The waters in these blue sands and gravels are highly mineralized, but the shallow water is of good quality.

Drillings in San Ardo Valley at the south end of the Upper Valley Area have been comparatively shallow. The alluvium generally ranges from 60 to 200 feet in depth and overlies a blue shale formation. The alluvium immediately east of San Ardo is composed in large part of material contributed from the watershed of Pancho Rico Creek, characterized by a high concentration of solubles.

Fluctuation in Ground Water Levels

Measurements of depths to water were made at 412 wells distributed over the valley floor in the Salinas Basin by the Division of Water Resources in the fall of 1931, and again in the spring and fall of 1932. County Engineer Howard Cozzens of the County of Monterey, since 1933 and through 1944, maintained records of water levels at 116 selected wells in the basin at the commencement and at the close of each irrigation season. These measurements provide valuable information for comparative purposes. Measurements were made by the Division of Water Resources at 520 wells in the fall of 1944, spring and fall of 1945, and in the spring of 1946. All wells measured between 1931 and 1944, that were still measurable, were incorporated as measuring wells in the recent series. These records of ground water levels at wells have been set forth with the basic data in Bulletin 52A.

Water level observations were made in 1916-17 by W. O. Clark, field engineer of the United States Geological Survey. The results of these measurements have been included in the 1933 publication by the Division of Water Resources entitled, "Record of Water Levels at Wells in Salinas Basin".

(1) Changes in piezometric level of the pressure surface in the Pressure Area do not indicate change in storage. Change in elevation of the water table at the forebay of the Pressure Area is the indicator of the change in storage that may be involved. If the water elevation at the fountain head shows no material drop after a season of pumping from a pressure area, then there has been no seasonal depletion and there will be substantially complete recovery of the pressure surface within a limited period of time after cessation of extractions.

Depths to water have been measured in seven wells at or near the fountain head of the 180-foot aquifer in the Pressure Area during the fall in the three critical dry years of 1931,

1933, and 1939, the very wet year of 1941 and moderately dry year of 1945. The average depth to water in these seven wells indicates the range in fluctuation of minimum annual water elevations at the head of the 180-foot aquifer as set forth in the following tabulation:

Well Number	Fall Measurements - Depth to Water				
	1931	1933	1939	1941	1945
5-E-23	76.1	76.0	70.0	64.0	67.2
5-E-59	38.2	42.9	33.0	26.0	30.9
5-F-1	31.1	29.2	27.0	21.5	25.7
5-F-9	23.0	19.6	19.5	10.0	10.5
5-F-10	20.8	20.0	16.0	9.5	12.8
5-F-14	35.6	32.2	35.0	24.5	29.0
5-F-26	47.2	50.6	44.5	39.5	43.4
Averages	38.9	38.7	35.0	27.9	31.4

The Salinas River flowed through the Forebay Area past the fountain head of the 180-foot aquifer throughout the summer and fall of 1941. The river ceased to flow into the Forebay Area near Metz on February 22, 1931, on February 25, 1933, on April 20, 1939, and on May 20, 1945, for the remainder of each year, respectively. The amount of seasonal depletion in the pressure surface of the 180-foot aquifer appears to vary inversely with the length of time the Salinas River flows during the year into the Forebay Area.

Automatic water stage recorders were installed and maintained during the investigation on six non-operating wells in the 180-foot aquifer about four miles apart between Gonzales and Monterey Bay. Two additional recorders were installed for shorter periods of time on non-operating wells near the bay shore. Each recorder well was situated more than one-fourth mile from any operating well. The recorders showed a fluctuation in elevation of the pressure surface of the 180-foot aquifer of about 15 feet during the irrigation season of 1945. The elevation varied inversely with the combined rate of draft on the 180-foot aquifer and the hydraulic gradient varied directly with the draft. All but less than one foot of the average recovery of the pressure surface after the close of the irrigation season in 1944 occurred prior to any replenishment of ground water in the basin from percolation of stream flow and precipitation. The small average recovery of less than one foot in the pressure surface of the 180-foot aquifer, after the Salinas River commenced to flow during the winter of 1944-45 indicates little seasonal depletion in the supply to the aquifer during 1944. The seasonal depletion was more in 1945 than during the previous year.

The pressure surface of the 400-foot aquifer was at substantially the same elevation during the winter of 1944-45 as that of the 180-foot aquifer. However, during the peak season of irrigation in 1945, piezometric levels were 10 to 12 feet lower in the 180-foot than in the 400-foot aquifer between Salinas and the bay shore. There are no deep wells available for comparison at the south end of the Pressure Area near the fountain head. The pressure surface of the 400-foot aquifer in the first well drilled therein near the bay shore in September, 1945, was approximately two feet above mean sea level.

Operation of wells Nos. 3-C-71 and 3-C-72, perforated in the 400-foot aquifer only, has no effect on water elevations in the nearby wells Nos. 3-C-24 and 3-C-40, which are perforated in free ground water overlying the 400-foot aquifer. Conversely, operation of the two shallow wells has no appreciable effect on piezometric levels of the pressure surface in the deeper

water-bearing formation. The easterly fringe of the 180-foot aquifer lies about one mile west of the junction of the San Juan Road with State Highway 1-1, which is the approximate location of the four wells above mentioned in this paragraph.

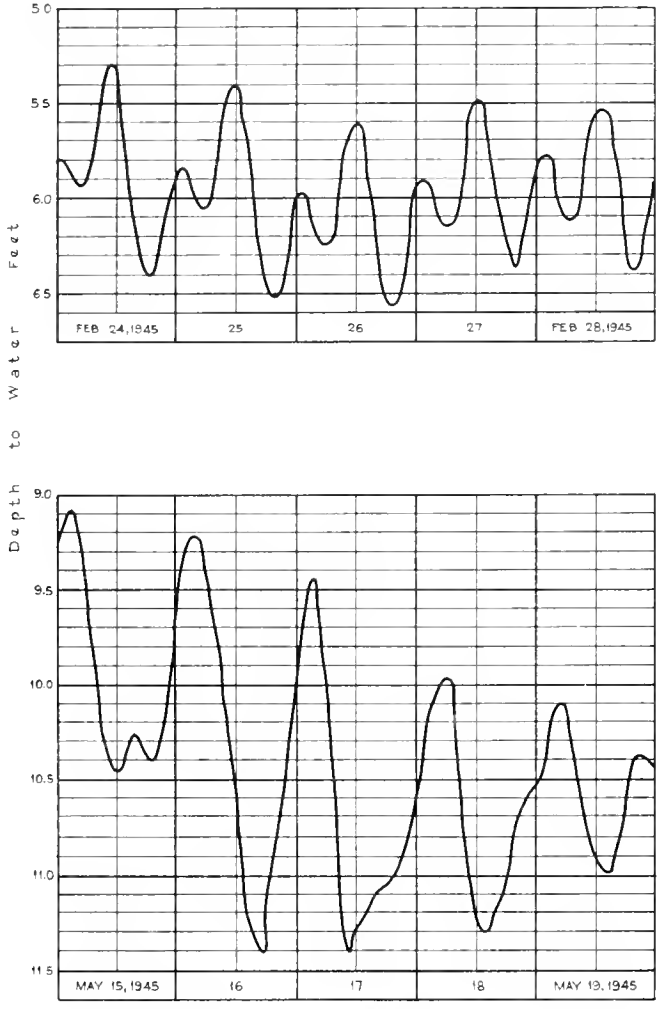
It was also observed that there was mutual interference among four wells in the 400-foot aquifer numbered 3-D-45, 3-D-48, 2-D-37, and 2-D-39, but the operation of these wells did not appreciably affect any of the nearby wells in the 180-foot aquifer, and vice versa. These observations lead to a conclusion that there is no interconnection of the two aquifers in this vicinity.

There were a number of flowing artesian wells in the 180-foot aquifer in the Salinas-Blanco area and between Castroville and the bay shore before irrigation became important in the Salinas Basin as is shown by measurements of water levels made by W. C. Clerk in 1915 and as set forth in Water Supply Paper No. 89 of the United States Geological Survey. There were a number of flowing wells during the winters of 1944-45 and 1945-46 on the low ground in the reclaimed beds of Espinosa Lake and Merritt Lake between Castroville and Santa Rita. Several wells flowed intermittently during the winter near Mulligan Hill as late as 1941. Increased municipal and industrial draft since 1941 has caused more pressure relief and lower prevailing water elevations during the winter season.

Records of behavior of the pressure surface of the 180-foot aquifer on the reproductions of recorder charts for two five-day periods on three wells are shown on Plates 4, 5 and 6. The draft during the period from February 24 to 28, 1945, was light and water elevations were near the high for the winter. The draft was moderately heavy between May 15 and 19, 1945, about six weeks after the commencement of the irrigation season. Tidal influence on the pressure surface near the bay shore is shown in the February period at well No. 1-C-53n on Plate 4. The tidal influence is largely obscured in the May period on Plate 4 due to fluctuations in draft between day and night. Well No. 2-C-147n situated near Blanco is above any appreciable tidal influence. The fluctuations in the February period on Plates 5 and 6 are largely due to variations in municipal, industrial, and domestic draft between day and night. There was a small amount of daytime irrigation for seed germination near the fountain head between Chualer and Gonzales during the last week in February, 1945. The sharpness of the daily fluctuations in the pressure surface near Blanco during the May period shown in Figure 4 are characteristic over the Pressure Area during the irrigation season except near the fountain head. The narrow curved range in fluctuation during the May period shown on Plate 6 at well 4-E-18n is typical of that near the fountain head, and approaches a merger in water table performance on free ground water under moderately heavy draft.

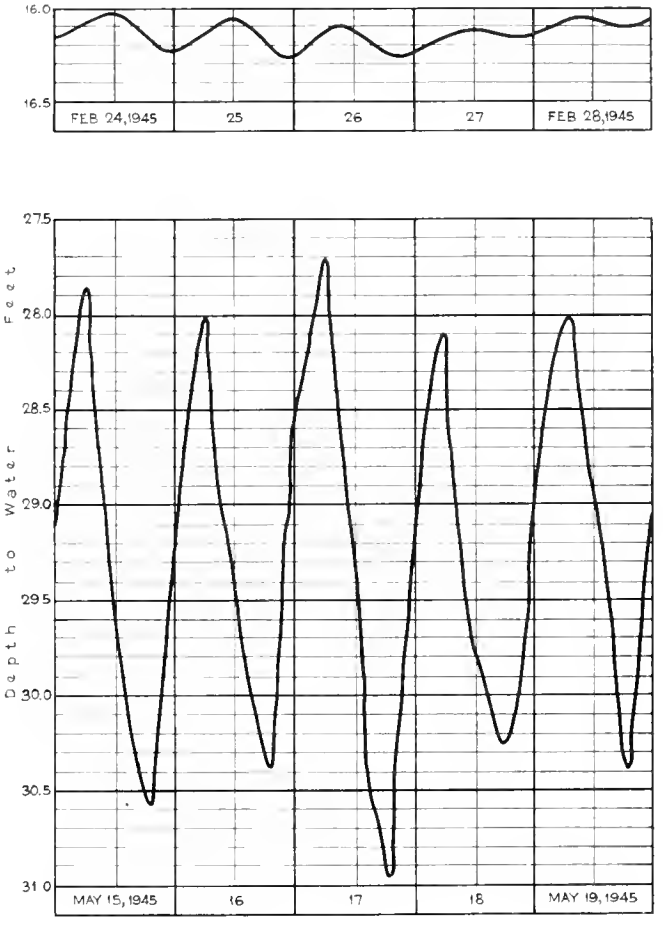
It is concluded from the foregoing discussion that fluctuations in elevation of the pressure surface and hydraulic gradient in the 180-foot aquifer in the Pressure Area in the Salinas Basin are largely governed by pressure relief induced by draft. Seasonal depletion of ground water storage above the fountain head has a minor effect in years close to normal, such as 1944 and 1945.

PLATE 4



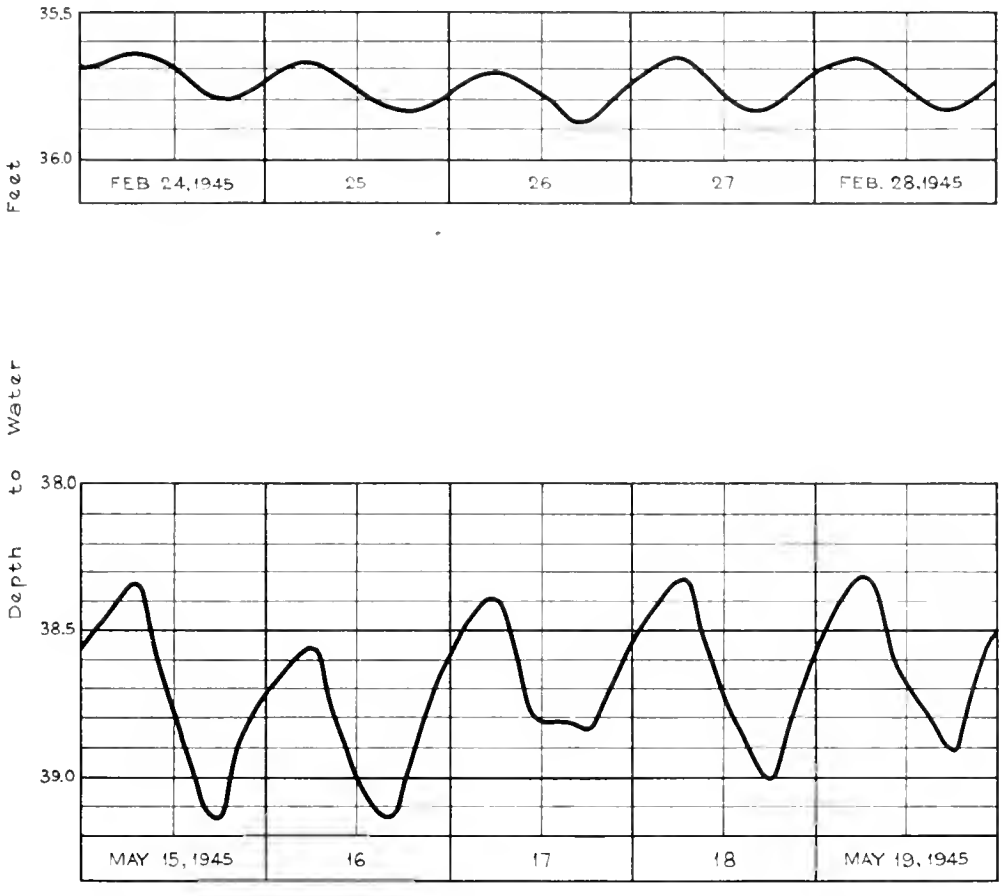
FLUCTUATIONS OF PRESSURE SURFACE
AT
WELL 1-C-53n

PLATE 5



FLUCTUATIONS OF PRESSURE SURFACE
AT
WELL 2-C-147n

PLATE 6



FLUCTUATIONS OF PRESSURE SURFACE
AT
WELL 4-E-18n

(2) Forebay Area changes in water table elevations in free ground water indicate change in underground storage. There are 13 wells scattered over the Forebay Area at which depths to water were measured in the fall and spring of 1931-32, which were also measured in 1944-45 and 1945-46. The measurements of depths to water in the fall of 1931 show prevailing water elevations at the end of one of the driest years of record, which was preceded by five successive dry years. The draft on ground water in the Salinas Basin in 1931 was the heaviest of any year prior to 1939, and was about equal to that in 1940, but exceeded the extractions in 1941 and 1942. The measurements made in the fall of 1944 indicate water elevations prevailing in the Forebay Area after the close of an irrigation season of the heaviest draft that had ever occurred. The year 1944 was slightly subnormal in precipitation, but it was preceded by four of the wettest years of record. The year 1945 was moderately dry and the draft was slightly greater than in 1944. Comparison of depths to water at the 13 measuring wells in the Forebay Area in the falls of 1931, 1944, and 1945 and the respective depths during the succeeding spring

are set forth in the following tabulation:

Well Number	Depths to Water in Feet					
	Fall 1931	Spring 1932	Fall 1944	Spring 1945	Fall 1945	Spring 1946
5-F-9	23.0	17.0	13.9	12.0	14.4	12.3
5-F-12	24.8	20.4	24.4	22.2	25.0	23.4
5-F-14	35.6	30.1	27.1	24.8	29.0	26.0
5-F-26	47.2	46.0	41.5	40.2	43.4	40.3
5-F-35	25.5	20.3	19.0	17.6	20.4	18.5
6-F-17	52.4	52.8	53.7	52.4	55.4	52.9
6-F-23	32.0	26.0	25.3	24.3	27.2	24.7
6-F-27d	50.5	48.1	44.5	43.7	46.4	43.8
6-F-30	18.9	11.7	12.8	9.7	13.8	10.4
6-F-32	13.5	10.1	9.0	8.0	12.4	9.2
6-F-36	45.6	33.4	36.6	33.8	38.1	34.9
7-F-1	111.8	104.8	104.2	101.7	106.4	102.6
7-G-42	47.4	33.1	36.7	32.0	38.0	30.2
Average	40.6	34.8	34.5	32.5	36.1	33.0

Water elevations in the Forebay Area in the springs of 1945 and 1946 were about as high as is possible to obtain from Salinas River percolation, i.e., the river would change from influent to effluent with an appreciably higher water table. The above tabulation shows an average recovery in water elevation at the 13 wells between fall and spring of 5.8 feet in 1931-32, 2.0 feet in 1944-45 and 3.1 feet in 1945-46. The average water elevation in these wells was 4.5 feet higher in the fall of 1945 than in the fall of 1931. The average water elevation at 71 measuring wells was 1.6 feet lower in the fall of 1945 than in the fall of 1944.

Intermittent observations made of the flow in the Salinas River in 1941, the wettest year of record, indicated accretions to flow throughout the summer in the Forebay Ares. Depths to water at only six of the above wells were measured in the fall of 1941. Comparative depths to water at the six wells in the falls of 1931 and 1941 and spring of 1945 are set forth in the following tabulation:

Well Number	Depths to Water in Feet		
	Fall 1931	Fall 1941	Spring 1945
5-F-9	23.0	10.0	12.0
5-F-14	35.6	24.5	24.8
5-F-26	47.2	39.5	40.2
6-F-17	52.4	51.0	52.4
6-F-23	32.0	24.0	24.3
6-F-32	13.5	14.0	8.0
Average	33.9	27.1	27.0

Water elevations in the Forebay Area in the fall of 1941 were about as high as is possible to obtain from Salinas River percolation. The average elevation at the above six wells in the fall of 1941 was nearly the ssme as in the spring of 1945, and was 6.8 feet higher than in the very dry yesr 1931. The electric energy used for agricultural purposes in the Salinas Basin in 1941 was approximately 90 per cent of that in 1931. Although the acreage irrigated in 1941 has hereinbefore been estimated as 112,000 acres as compared with 109,600 in 1931, there was less demand for irrigation water in 1941 due to availability of rainfall to supply a portion of the water requirements.

The average difference in ground water elevations between spring and fall at 42 wells in the Forebay Area in 1931 was 3.7 feet. A portion of this apparent seasonal depletion was replenished from ground water inflow from the Arroyo Seco Cone and the Upper Valley Area prior to

the occurrence of runoff the following winter. Eight control wells in the Forebay Area at which depths to water were measured in the fall series of 1944, during the last week in November, were measured again on January 8 and 9, prior to the occurrence of any flow to the area from the Salinas River during the winter with results as shown in the following tabulation:

Well Number	Depths to Water in Feet	
	November 25, 1944	January 8, 1945
5-F-14	27.1	26.1
5-F-26	41.5	40.4
5-F-35	19.0	19.3
6-F-17	53.7	53.1
6-F-41i	35.2	35.0
6-F-36	36.6	37.2
7-F-1	104.2	102.9
7-F-11	32.2	31.6
Average	43.7	43.2

The average recovery in water elevations in the above eight wells in the Forebay Area prior to the occurrence of flow in the Salinas River was approximately 25 per cent of the total recovery between fall and spring measurements.

Spring and fall measurements of depths to water were made at 38 wells in 1945. The average difference in elevation at the 38 wells between spring and fall was 4.5 feet as compared with 3.7 feet in 1932. The use of water in the Salinas Basin was materially greater in 1945 on 126,700 acres of irrigated land than in 1932 when the irrigated area embraced 97,800 acres. The average recession in water elevations at the measuring wells in the Forebay Area in 1945 was approximately 22 per cent greater than in 1932. Measurements, which were made during the first week in March 1946, of depths to water at 31 of the measuring wells used in the Forebay Area in 1945 showed an average recovery of 4.2 feet during the winter of 1945-46. The Salinas River had almost ceased to flow through the Forebay Area on March 1, 1946, and pumping for irrigation had commenced on seven of the 1945 measuring wells. Heavy storms during the latter part of March, 1946, caused a large increase in the flow of the river, as a result of which some additional recovery may have occurred.

Spring and fall measurements of depths to water made by the County of Monterey in 1935, 1940, and 1944 at six wells in the Forebay Area further indicate the narrow range in seasonal depletion of ground water storage in the Forebay Area. The results of these measurements follow:

Well Number	Depths to Water in Feet					
	Spring 1935	Fall 1935	Spring 1940	Fall 1940	Spring 1944	Fall 1944
5-F-9	16.6	20.8	11.0	16.0	14.8	13.9
5-F-31	26.0	27.6	15.0	18.0	12.0	16.5
6-F-17	56.6	57.0	51.0	56.0	54.0	53.7
6-G-2	23.0	21.8	19.0	22.0	19.2	21.0
7-G-55	54.0	56.0	51.0	55.0	52.8	55.1
8-H-20	56.6	52.7	49.0	51.0	54.4	48.9
Average	38.8	39.3	32.7	36.3	34.5	34.9
Annual Change	0.5		3.6		0.4	

(3) The Arroyo Seco Cone ground water elevations have the widest range in seasonal fluctuation of any in the Salinas Basin. Nineteen of the measuring wells on the cone that were used by the Division of Water Resources in the 1931 and 1932 series of measurements were again used in the 1944 and 1945 series. Comparative water elevations are indicated in the following tabulation:

Well Number	Depths to Water in Feet					
	Fall 1931	Spring 1932	Fall 1932	Fall 1944	Spring 1945	Fall 1945
6-G-11	8.8	7.1	10.7	6.9	4.3	7.8
6-G-29	35.2	24.3	28.3	30.0	27.5	26.0
7-G-4	19.7	12.1	15.5	13.1	10.0	13.8
7-G-10	19.8	7.7	9.0	16.8	11.1	14.3
7-G-14	28.5	11.0	25.0	22.1	17.9	22.2
7-G-15	23.0	13.9	19.6	14.2	9.2	15.4
7-G-23	39.8	21.5	24.3	29.8	25.2	30.7
7-G-25	32.4	21.9	23.7	23.2	16.4	23.9
7-G-28	66.3	16.3	33.8	30.2	21.0	31.2
7-G-31	42.2	31.6	35.8	37.4	26.9	39.1
7-G-35	70.4	46.0	70.3	55.9	42.3	59.9
7-G-44	51.2	26.8	46.2	36.6	30.8	39.7
7-G-45	45.2	34.8	40.2	32.0	21.8	34.1
7-H-1	152.7	141.5	149.8	144.2	129.9	147.4
7-H-4	52.5	34.0	40.8	40.4	35.3	44.0
7-H-8	138.0	136.4	139.0	148.3	135.1	146.7
7-H-9	115.8	97.2	105.6	98.4	93.0	101.8
7-H-12	113.5	130.0	125.0	121.1	111.5	124.8
7-H-17	129.8	104.8	125.0	127.2	111.2	128.7
Average	62.3	48.3	56.2	54.1	46.3	55.3

The foregoing tabulation indicates an average recovery in water elevations in the Arroyo Seco Cone between the fall of the dry year, 1931, and the spring of the above normal year, 1932, of about 14 feet. The average drop in water elevations at the 19 wells between spring and fall in 1932, was 7.9 feet as against 9.0 feet in 1945. The recovery between the fall of 1944, and the spring of 1945, was about 7.8 feet. There was an average net rise in water elevations at the 19 wells between the fall of 1931, and the fall of 1945, of 7.0 feet. While no measurements were made of depths to water in the fall of 1929, at the beginning of the 16-year base period hereinbefore discussed in Chapter IV, the probable percolation from the Arroyo Seco, consumption of water in the Arroyo Seco Cone and estimated ground movement therefrom indicate water elevations in the fall of 1929, were between those in the falls of 1931 and 1932. The average recovery in water elevations at 23 wells in the Arroyo Seco Cone between the fall of 1945 and the spring of 1946 was 9.9 feet.

There were only four wells in the Arroyo Seco Cone at which depths to water were measured in the spring of 1941, the wettest year of record. The average water elevation at these four wells was 4.2 feet higher in the spring of 1941 than in 1945, which indicates additional capacity for percolation existed in 1945. Even if the cone were fully recharged, the minimum rate of percolation in the cone should exceed the maximum rate of ground water movement therefrom, which is in excess of the estimated average rate of 31,000 acre-feet per annum as previously set forth in Chapter V.

(4) The Upper Valley Area appears to have had substantially complete ground water replenishment each year since commencement of records thereon in 1931-32. Ten of the measuring wells used in the spring of 1932 in this area were used in the spring series of measurements of depths to water in 1945 and 1946, with the following results:

Well Number	Depths to Water in Feet		
	Spring 1932	Spring 1945	Spring 1946
8-H-31	88.7	[illegible]	89.[illegible]
8-H-33	192.3	183.9	183.5
8-I-1	74.3	[illegible]	[illegible]
9-I-1	52.6	[illegible]	49.4
9-I-4	61.0	60.[illegible]	[illegible]
9-I-10	57.3	54.[illegible]	[illegible]
10-J-1	14.0	[illegible]	13.4
11-J-2	13.5	10.0	[illegible]
11-K-1	60.3	[illegible]	[illegible]
12-K-3	68.7	68.5	68.[illegible]
Average	68.3	65.5	65.6

The elevation of the water table in the Upper Valley Area during the spring is largely governed by the elevation of water surface in the Salinas River in years of normal or subnormal precipitation. In very wet years such as 1941, there is doubtless contribution to ground water direct from precipitation over the area and the river may become effluent. Depths to water were measured at the same six wells in the Upper Valley Area in the spring of the very dry year, 1939, and in the spring of 1941, with the following results

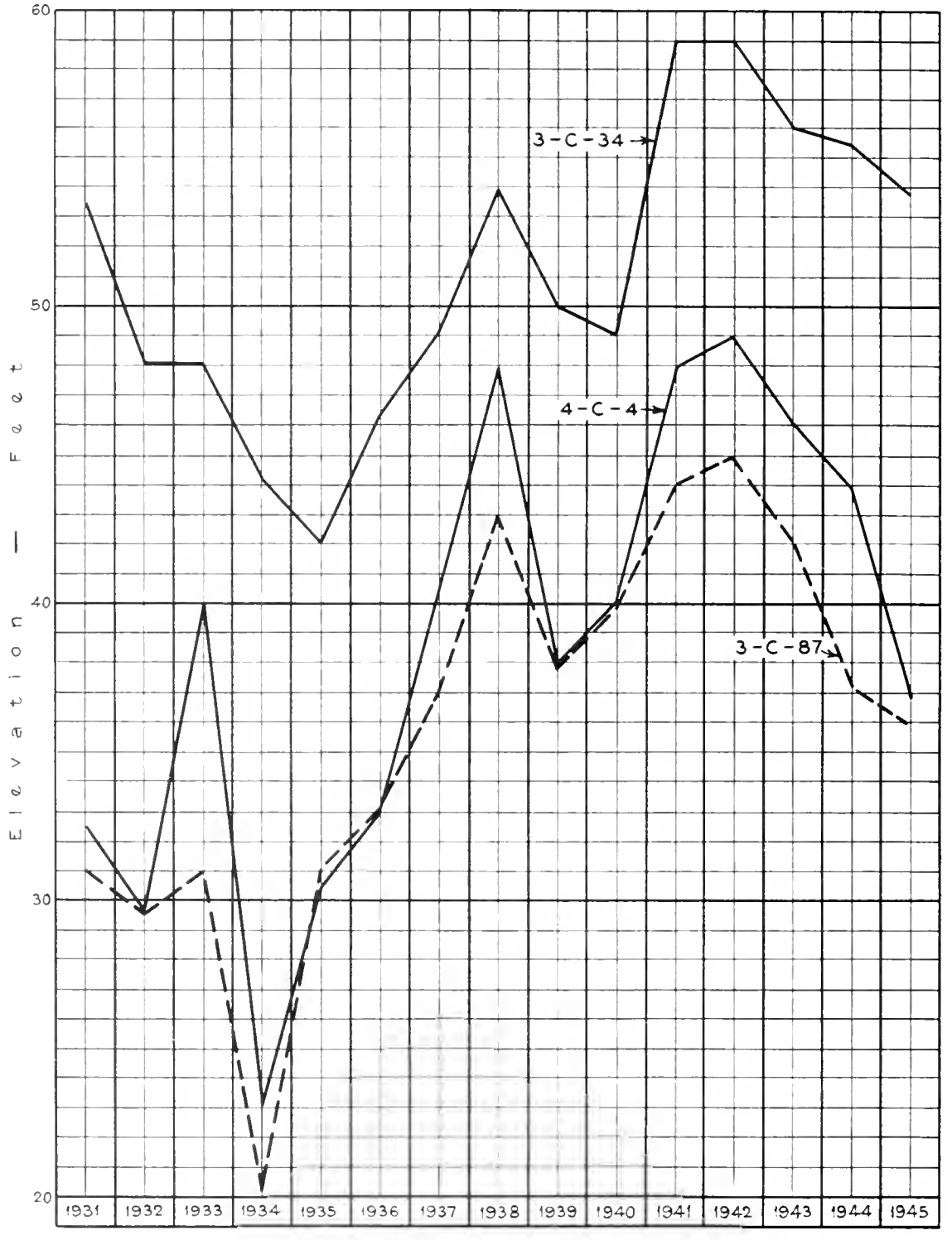
Well Number	Depths to Water in Feet	
	Spring 1939	Spring 1941
8-H-31	82.0	76.0
9-H-9	12.0	10.0
9-I-2	9.0	5.0
9-I-17	53.0	46.0
10-J-1	14.0	12.0
12-K-5	55.0	50.0
Average	37.5	33.2

The average water elevation at 41 measuring wells in the Upper Valley Area was 1.5 feet lower in the fall of 1945 than in the fall of 1944.

(5) East Side Area ground water elevations in the fall of 1945 were depressed below those prevailing in the fall of the dry year, 1931, in districts where heavy irrigation development has occurred in recent years. There was substantial recharge of ground waters in this area between 1936-37 and 1941-42, during which six-year period the rainfall at Salines was 132 per cent of the meen. The precipitation at Salinas during the three-year period, 1939-40 to 1941-42, was 148 per cent of the mean, it being the wettest three year period of record. The depletion of ground water storage has largely occurred during the succeeding three years of heavy draft, 1942-43 to 1944-45, when precipitation at Salinas was close to normal. Charts of the water elevations of three wells in the East Side Area, at which depths to water have been measured each fall from 1931 to 1945, inclusive, shown on Plate 7, indicate typical performance of the water table in the East Side Area.

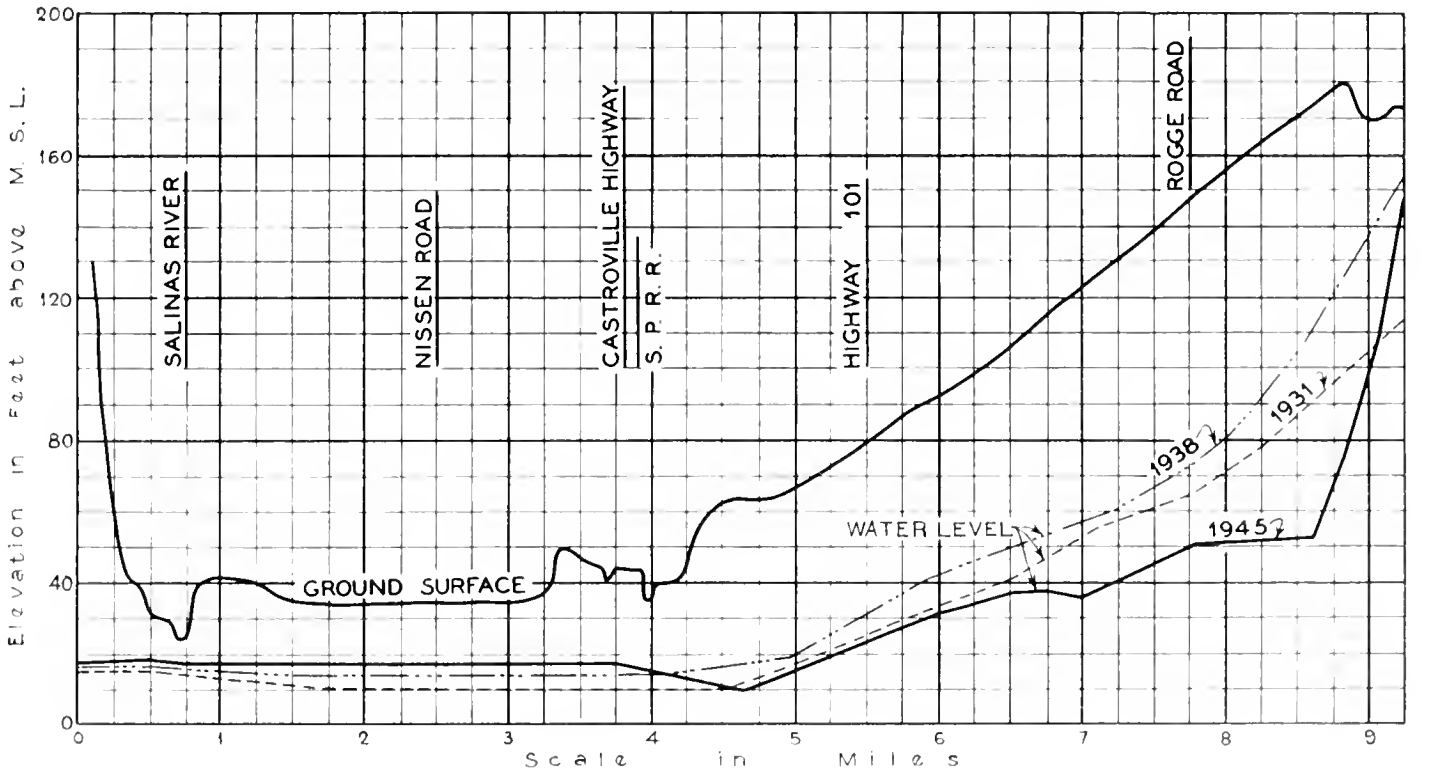
Cross-sections along the lines of the Davis and Spence Roads depicting profiles of ground surface and water elevations in the falls of 1931, 1938, and 1945 are shown on Plates 8 and 9, respectively. The rise in water elevation in these districts in 1938, and the drop since then appear from the profiles. It may be noted, however, that there has been a slight rise in the pressure surface in the adjoining Pressure Area, which indicates less seasonal depletion in 1945 than in 1931 in the interconnected Forebay and Pressure Areas.

PLATE 7



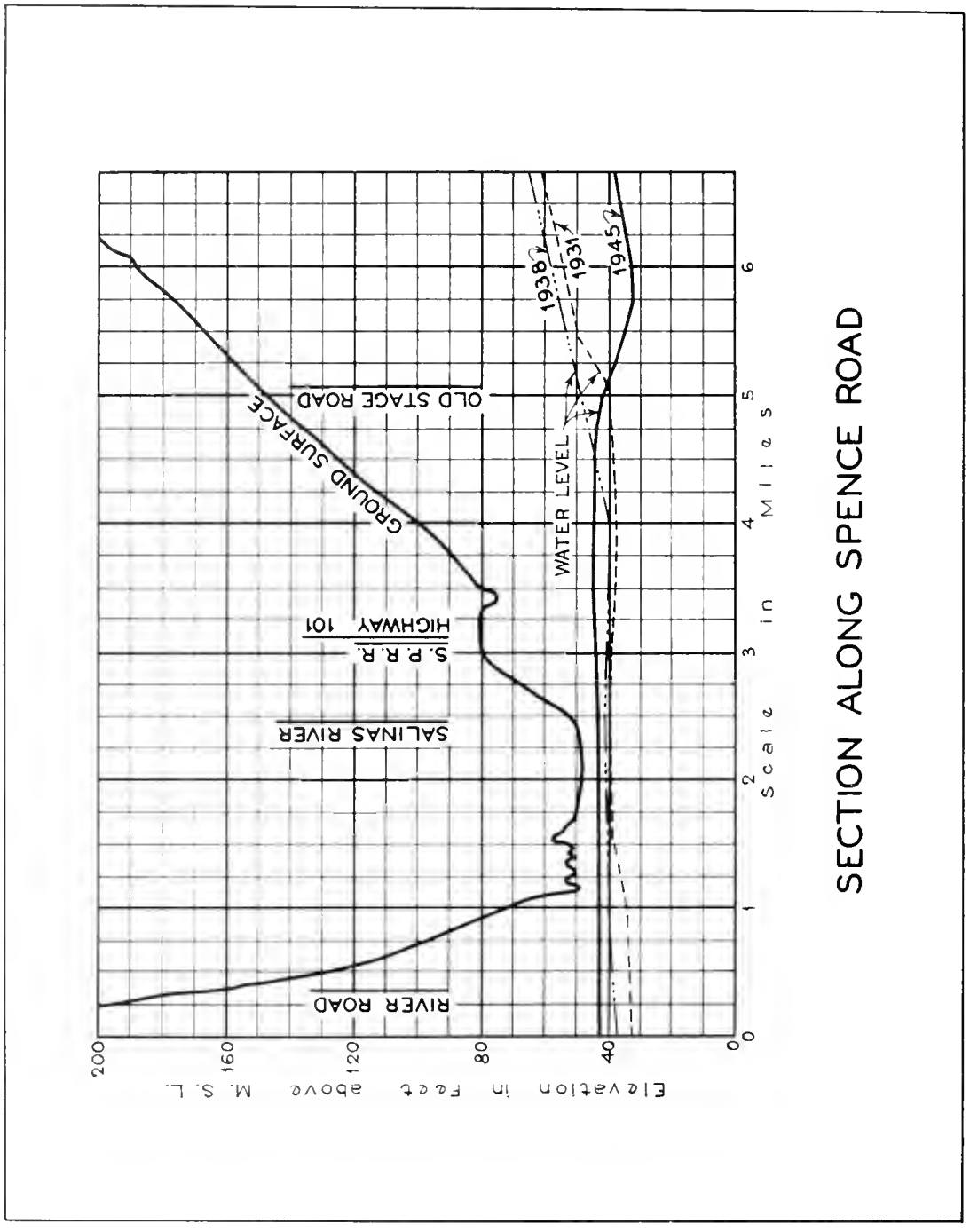
FALL WATER ELEVATIONS AT CONTROL WELLS
EAST SIDE AREA

PLATE 8



SECTION ALONG DAVIS ROAD

PLATE 9


SECTION ALONG SPENCE ROAD
Elevation in Feet above M. S. L.
200
160
120
80
40
0
Scale in Miles
0
1
2
3
4
5
6
RIVER ROAD
SALINAS RIVER
S. P. R. R.
HIGHWAY 101
OLD STAGE ROAD
GROUND SURFACE
WATER LEVEL
1938?
1931?
1945?

Depths to water were measured at 47 wells in the East Side Area in the fall of 1944 and spring and fall of 1945. The average depth to water in the 47 wells was 4.0 feet greater in the fall of 1945 than in the fall of 1944. The average net difference in water elevations at the 47 wells between spring and fall in 1945, was 7.2 feet.

The elevation of the water table in the free ground water areas and piezometric levels in the 180-foot aquifer in the alluvial fill of the Salinas Basin in the fall of 1944, are indicated on Plates 17 to 21, inclusive, at the end of the report. Lines of equal water elevations with 5-foot contour intervals are shown on these plates. The contours were originally drawn at 2-foot intervals at a scale of four inches to the mile to secure more accurate detail. These were then reduced by photostatic process to a scale of two inches per mile and the 5-foot intervals were interpolated. Plates 17 to 21, inclusive, are lithograph reductions of the originals on a scale of two inches per mile.

Specific Yield

The difference between total inflow, including precipitation on the valley, and total outflow from the Salinas Basin, during the runoff year 1944-45, has hereinbefore been computed as 383,000 acre-feet. The gross consumption of water in the basin as determined by the integration method hereinafter set forth in Appendix C, is estimated as 433,000 acre-feet in 1944-45. The difference between consumption and gross retention of 50,000 acre-feet is a measure of estimated change in ground water storage for the year.

The total soil volume drained between the fall of 1944 and fall of 1945 in the areas of free ground water in the basin is indicated in the following tabulation:

Area	Acreage	Change in Water Level	Soil Volume Drained Acre-Feet
Upper Valley	59,073	-1.50'	88,500
Forebay	40,373	-1.56'	83,000
Arroyo Seco	22,115	-1.20'	26,500
East Side	36,477	-4.00'	146,000
Pressure	5,000	-3.57'	18,000
Total	163,038	-2.22'	362,000

The indicated average specific yield for a change in ground water storage of 50,000 acre-feet in the free ground water areas at the water levels prevailing 1944-45 is approximately 13.8 per cent. It is assumed that no change in storage occurred through changes in piezometric levels in the confined water section of the Pressure Area, which appears to embrace a gross area of nearly 76,000 acres. There was no appreciable change in perched water elevations in the Pressure Area between the falls of 1944 and 1945.

It is probable that specific yields range somewhat higher in the Upper Valley and Forebay Areas and the free ground water section of the Pressure Area than in the Arroyo Seco Cone and East Side Area. There is less uniformity in the water-bearing formations in the Arroyo Seco Cone and East Side Areas where the principal sources of alluvium are the adjacent mountains. The gravels and sands in the Upper Valley, Forebay and Pressure Areas have been transported from more distant watersheds and a correspondingly greater degree of uniformity prevails in the forma-

tions. It is also possible that specific yields will decrease appreciably at greater depths.

Underground Storage Capacity

An estimate was made in the 1933 report by the Division of Water Resources of the amount of storage underground in the free ground water area in the Salinas Basin between water levels prevailing in the fall of 1932 and a static level of 125 feet below the ground surface. Fourteen samples of surface material of various classes found in stream beds and exposed cut banks were analyzed at that time to obtain specific yields. The classes of materials in the 125-foot zone were calculated by groups of wells from 266 identified logs. Additional well logs that have been collected since the 1933 report do not indicate any material difference except in the extent of the zone of confined water in the Pressure Area. It now appears that the areas of 16,600 acres formerly included in the west zone and 9,000 acres included in the river zone between Chualar and Gonzales are either in the Pressure Area, or are in sufficient proximity to the fountain head of the 180-foot aquifer that the storage cannot be drawn down without a decrease in the rate of movement of ground water through the aquifer in which an overdraft presently exists.

As hereinbefore set forth, the water levels in the areas of free ground water in the Salinas Basin in the fall of 1945 were substantially the same as in the fall of 1932, except in the East Side Area and in the section of unconfined water in the Pressure Area. Since the present consumptive use of ground water in all of the area adjoining the confined water in the Pressure Area on the east exceeds the average annual recharge, the storage there is in the process of exhaustion. The overdraft in those portions of the East Side Area, where the water bearing formations have contact with the aquifers in the Pressure Area, will be supplied by the confined waters, which will tend to accentuate the manifestations of overdraft in the northerly portion of the latter area. It therefore appears that the economy of the basin will be adversely affected by further exhaustion of the storage in the free ground water area lying east of the zone of confined waters in the Pressure Area.

The zoning of the storage in the Salinas Valley to a depth of 125 feet below ground surface, as set forth in the 1933 report of the Division, has been modified to conform to the areas used in this report for analytical purposes as follows:

Area	Acres	Total Acre-Feet
Upper Valley	49,500	575,000
Forebay	40,000	410,000
Arroyo Seco Cone	20,000	165,000
East Side	26,000	140,000
Pressure (East Side)	5,000	20,000
Pressure (South)	21,600	230,000
	162,100	1,540,000

As above stated, the last three items in the foregoing tabulation covering an estimated total of 390,000 acre-feet is not considered to be usable ground water storage. These items cover the estimated storage within the 125-foot zone as of 1932 water levels in the free ground water area east of the confined waters in the Pressure Area and near the fountain head of the

180-foot aquifer. The estimated 160,000 acre-feet on the East Side was somewhat less in the fall of 1945, but there has been no substantial change in other areas.

The usable ground water storage within the 135-foot zone, estimated as 1,150,000 acre-feet, is about half in the Upper Valley area and the remainder in the Arroyo Seco Cone and Forebay Area. The Upper Valley Area is quite remote from other areas in the Salinas Basin where additional water is required with the exception of about 14,000 acres of local irrigable land not heretofore irrigated. If it is assumed that the entire 14,000 acres will ultimately be brought under irrigation with the types of crops presently irrigated and with no change in prevailing irrigation practices, an additional average annual draft on ground water in the Upper Valley of about 11,000 acre-feet could occur for local use as hereafter set forth in Chapter IX. For all practical purposes at this time, the remaining ground water storage in the Upper Valley Area may be classed as not usable in other areas having requirements for additional water.

(1) The Forebay Area and Arroyo Seco Cone are so situated, adjacent to the East Side and Pressure Areas, that development of ground water storage therein is possible to supply existing deficiencies and to meet increasing requirements below the Upper Valley Area. Since the ground water in the Forebay Area and lower portion of the Arroyo Seco Cone receives complete annual replenishment, except in critical dry years, the estimated storage of 575,000 acre-feet seems large as compared with ultimate requirements as hereinafter set forth in Chapter IX.

A map showing lines of equal depths to water in the Forebay Area and Arroyo Seco Cone in the fall of 1944 with 2-foot contour intervals was prepared on a scale of four inches to the mile. The respective acreages embraced in the Forebay Area and lower portion of the Arroyo Seco Cone between depths to water of six to 30 feet, 30 to 45 feet, and 45 to 60 feet were determined by the map weighing method previously described with the following results:

Depth to Water in Feet		
Range	Average	Acreage
6 to 30	22	25,000
30 to 45	38	14,700
45 to 60	52	5,100
	Total	44,800

The estimated underground storage in the fall of 1944 above a static level of 60 feet below ground surface in the Forebay Area and Arroyo Seco Cone with an assumed average specific yield of 10 per cent is shown in the following tabulation:

Acreage	Average Depth of Saturation 60-Foot Zone	Soil Volume Acre-Feet	Estimated Storage Acre-Feet
25,000	38'	950,000	95,000
14,700	22'	320,000	32,000
5,100	8'	40,000	4,000
Totals	29'	1,310,000	131,000

The average depth of saturated soil over the 44,800 acres in the 60-foot zone in the Forebay Area and Arroyo Seco Cone was approximately 29 feet in the fall of 1944. Water levels may recede in critical dry years, such as 1931, about 6 feet from the elevations prevailing in

these areas during the fall of 1944. The estimated storage above the 60-foot zone with an assumed specific yield of 10 per cent thus may approach 100,000 acre-feet in critical dry years.

(2) Capacity for additional underground storage exists generally over the East Side Area and in the bench lands on both sides of the Arroyo Seco in the upper portion of the Arroyo Seco Cone. The bench lands in the Arroyo Seco Cone range from 150 to 250 feet in elevation above the stream bed of the Arroyo Seco. The storage capacity in the bench land under the Clark Canal, which diverts from the Arroyo Seco to the Greenfield district, is largely recharged in normal years through percolation from the canal and from the unconsumed portion of water applied to lands irrigated thereunder.

A map showing lines of equal depths to water in the fall of 1944 in the free ground water area lying east of the confined waters in the Pressure Area between the Gloria Road at Gonzales and Merritt Lake was prepared on a scale of four inches per mile. The respective acreages embraced in the area between depths to water of 60 to 100 feet, 100 to 140 feet, 140 to 180 feet, and over 180 feet were determined by the map weighing method previously described with the following results:

Depths to Water in Feet

Range	Average	Acreage
60 to 100	80	14,400
100 to 140	120	6,400
140 to 180	160	4,500
over 180	190	6,400
	Total	31,700

There was an area of about 9,800 acres adjoining the confined waters on the east with static levels of less than 60 feet in the fall of 1944. The estimated empty underground storage capacity east of the confined waters between the water table prevailing in the fall of 1944 and 60 feet below the ground surface with an assumed average specific yield of 10 per cent is shown in the following tabulation:

Acreage	Average Depth Drained Soil Below 60-foot Zone	Soil Volume Acre-Feet	Estimated Empty Storage Capacity Acre-Feet
14,400	20'	290,000	29,000
6,400	60'	380,000	38,000
4,500	100'	450,000	45,000
6,400	130'	830,000	83,000
Total	62'	1,950,000	195,000

Irrigation Demand in Pressure Area

There was electric service through 610 meters to 632 irrigation wells in the Pressure Area between April 1, 1944 and March 31, 1945. There were only four diesel installations on operating irrigation wells during this period in the Pressure Area. An estimate, based on electric energy consumption, has been made of irrigation draft during this period in the Pressure Area.

The KWH power consumption was utilized for many meter numbers under irrigation service for the "power year", April 1, 1944 to March 31, 1945. There were many valuable pump tests of overall efficiency of irrigation installations in the Pressure Area as hereafter set forth in Table 2 of Appendix A. The pump tests reveal a range in overall efficiency between 27 and 71 per cent. Recent installations with meter numbers in the 40,000-series have an average efficiency of about 60 per cent whereas old installations with meter numbers below the 15,000-series run about 40 per cent. Where recent tests had not been made, efficiencies were assumed between 40 and 60 per cent, based on the age of the pumping plant.

Where gross pumping lift had not been measured under operating conditions, it was determined by adding the static lift between the discharge and the pressure surface, as measured in the fall of 1944, to estimated average drawdown plus the boost above the discharge as measured by depth of water in the standpipe above the discharge pipe under average operating conditions. The boost above the discharge pipe, including friction loss, in general is small in the Pressure Area due to comparatively flat terrain. Many of the pumping plants are situated on the highest part of the tract served and discharge into open ditches. The average drawdown of the pressure surface of the 180-foot aquifer, including mutual interference under operating conditions during the irrigation season in 1944 was estimated as 25 feet. There was no irrigation demand in the Pressure Area during the period from November 1, 1944 and March 31, 1945. Substantially all of the electric energy consumed in pumping irrigation water during the power year occurred between April 1 and October 31, 1944.

The number of acre-feet pumped by each plant equipped with an electric motor in the Pressure Area for irrigation purposes was computed from the following formula:

$$\text{Acre-feet} = \text{Efficiency} \times \text{KWH}/1.02 \times \text{total lift}.$$

The combined calculated amount of water pumped for irrigation purposes in the Pressure Area during the 1944 irrigation by installations motored with electric energy was approximately 102,000 acre-feet. It is estimated that combined extractions by the four diesel plants were about 500 acre-feet. The average acreage served per well was about 78 acres. An independent approach to determination of pumping for irrigation purposes during the 1944 irrigation season in the Pressure Area, as well as in the remainder of the Salinas Basin, is hereafter set forth in Appendix C. A third method of determination of extractions of ground water in the Pressure Area during the 1945 irrigation season is set forth later in this chapter.

Direct Determination of Flow Through 180-Foot Aquifer

Probability of marine intrusion in the 180-foot aquifer near the delta section of the Pressure Area during recent years was a primary reason for the Salinas Basin Investigation. Wells were being abandoned in this section at an accelerated rate in 1943 and 1944 because of excessive salinity in the waters of this aquifer.

If the salinity was occurring because of marine intrusion, then it follows that the pressure surface of the 180-foot aquifer must be depressed below mean sea level for a substantial period of time. It is fundamental that the hydraulic gradient must be downward from the bay shore for a certain distance inland to cause movement of sea water into the aquifer. Under such condi-

tions, of course, the aquifer must not be sealed from contact with sea water by an impervious barrier. A further condition that necessarily exists is a downward slope of the ground water hydraulic gradient from the upper reaches of the aquifer toward the bay if there is substantial replenishment through flow from the Forebay Area. This results in a trough in pressure surface elevations along the line of zero forward movement of ground water where the hydraulic gradient changes from a downward to an upward slope. It was determined in August, 1944, that such a trough did exist between Blanco and Nashua. The general position of the average hydraulic gradient is indicated by the line A-D-C in the diagrammatic sketch shown on Plate 10. The position and behavior of the trough was utilized during the 1945 irrigation season to directly determine the rates of safe yield and overdraft and to delimit the possible encroachment of marine intrusion in the 180-foot aquifer. A detailed explanation of the method is hereafter set forth, because so far as is known, it has not heretofore been used.

(1) Hydraulic Considerations

If a trough in water elevations is found to exist at any time under the above stated conditions, then all draft from the aquifer on the inland side of the trough is being replaced at that time by ground water flow from the upper portion of the basin toward the bay. Conversely, the draft between the trough and the shore line is being supplied at the time by movement of ground water inland from the bay. These premises are based on the fundamental axiom that water flows in the direction of the slope of the hydraulic gradient, which requires no proof.

It therefore follows, if the 180-foot aquifer is not effectively sealed from contact with ocean water, marine intrusion may approach but cannot extend beyond the farthest inland position of the trough in the pressure surface. The rate of safe yield of the aquifer from the standpoint of quality of water is equivalent to a rate of combined draft that would maintain such a trough behavior and position that the ground waters in the delta section near the shore line would remain usable for prevailing beneficial uses.

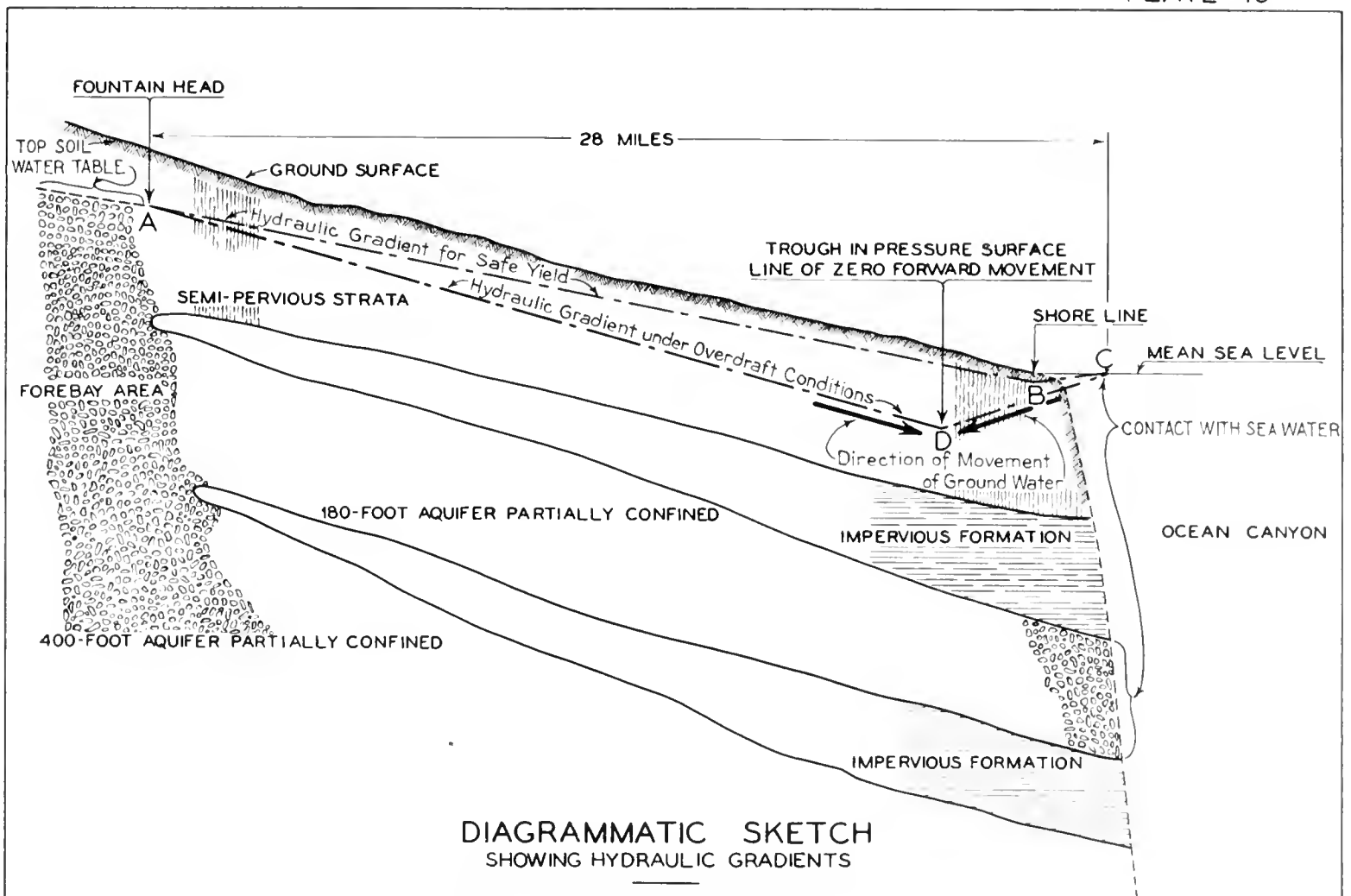
(a) Period of Effective Lag

An important preliminary consideration is the lag in stabilization of the pressure surface in a pressure area after a change in rate of draft. This phenomenon has been widely observed in many pressure areas and has been variously explained. The fact of its occurrence, rather than the reason therefor, is important in the considerations hereafter set forth. Theoretically a pressure surface may never reach an entirely stable condition under a specified draft, but after a limited period of time, further changes in the elevation become so minute that for all practical purposes it has stabilized. The period of time required to effect stabilization of the pressure surface after a change in rate of draft is herein referred to as the "effective lag". The error introduced by neglecting the change in elevation of the pressure surface after the period of effective lag is thought to be minute. The effective lag may readily be determined by observation of the performance of the pressure surface as shown by automatic recorders installed in various non-operating wells over the area, situated outside the immediate cone of pressure relief of operating wells.

(b) Trough Position

The position of the trough at any time is determined not only by the rate of draft at the time, but also by conditions of draft throughout the preceding period of effective lag.

PLATE 10



DIAGRAMMATIC SKETCH

SHOWING HYDRAULIC GRADIENTS

PRESSURE SURFACE OF 180-FOOT AQUIFER

A-B-C FOR SAFE YIELD RATE
A-D-C WITH OVERDRAFT

The draft throughout the pressure area (area of confined water) on both sides of the trough contribute to its position and behavior as is hereafter explained. The average rate of combined draft, or continuous flow equivalent of combined draft, inland from the trough during the effective lag period is a measure of the average rate of flow of ground water through the aquifer toward the bay under the average prevailing hydraulic gradient for the period. On the other side, the continuous flow equivalent of combined draft between the trough and the shore line during the effective lag period is a measure of the average rate of overdraft for the entire area under existing conditions for the period.

A trough in the pressure surface commences to form a short distance inland from the shore line when the continuous flow equivalent of combined draft on the aquifer during the effective lag period is slightly in excess of the rate of safe yield, if marine intrusion is possible. This is equivalent to the rate of flow through the aquifer for an average hydraulic gradient showing a head loss approximately equal to the water elevation at the fountain head above mean sea level. Also a prevailing trough in water elevations will become more shallow and approach the shore line as the average rate of draft decreases and approaches the rate of safe yield. Observations of total draft during the effective lag period immediately preceding the commencement of a trough and preceding its disappearance give two figures between which the rate of safe yield should lie.

(c) Trough Behavior

The behavior of the trough under changing conditions of draft may be anticipated. If the rate of draft increases, the rate of ground water movement must also increase, which increase is affected by steeper slopes in the hydraulic gradients on both sides of the trough. This in turn causes the trough to be further depressed in elevation, and the shorter distance to the shore line results in a more rapid change in the slope than in the greater distance from the trough to the fountain head. This condition naturally tends to force a larger proportion of the draft load to be moved to the ocean side of the trough and to cause the line of zero forward movement of ground water to shift farther inland. Conversely, as the rate of draft decreases, the downstream rate of movement of ground water decreases more slowly on the inland side than on the ocean side and the trough tends to rise and move toward the shore line. These considerations are predicted on comparable coefficients of permeability of the formation in the aquifer on both sides of the trough.

An increase in rate of draft on the bay side of the trough under conditions of steady extractions on the inland side steepens the slope of the hydraulic gradient on the bay side with a tendency to shift the trough toward the shore line. This in turn causes some of the load to move to the inland side which results in a steeper inland hydraulic gradient. The net effect thus is a drop in elevation of the trough and a downstream movement of its position. An increase in slope of the hydraulic gradient from the ocean toward the trough results in a greater rate of ground water flow from the bay inland, which necessarily means an increase in rate of overdraft.

(d) Data Required Under Direct Method

A determination of rates of safe yield and overdraft from the foregoing considerations involves only the following three items of information:

(1) Periods of effective lag on increase and decrease in rates of draft.

(2) Positions of the trough in pressure surface elevations.

(3) Draft above and below the trough.

The methods used in collection of these data during 1945 for the 180-foot aquifer in the Pressure Area of the Salinas Basin are hereinafter described. Reliable information on draft involves considerable detail, but the expense is small compared with possible unnecessary expenditures or damages that would accrue either in overdevelopment of enhancement of supply or in underestimates due to gross errors in the determination of overdraft.

The data obtained from observation are the result of the integration of all the obscure forces acting so that none need to be evaluated. What is sought from the data is the combined value of coefficient of permeability (P) and the cross-section of the aquifer (A). The known data are (Q) the draft, (h) the elevation of fountain head and of bottom of trough with reference to sea level, and (l) the distance from the fountain head to the trough and from the trough to the ocean canyon.

The general equation is $PA = Q^1/h$. It may be differentiated by appropriate suffixes such as "i" for the inland side of the trough, "o" for the ocean side, and "s" for the entire length from fountain head to ocean shore. The weighted average of $(PA)_i$ and $(PA)_o$ is $(PA)_s$. Then $Q = (PA)_s \frac{h_s}{l_s}$ just prior to appearance of a trough and just subsequent to its disappearance.

This calculated value of rate of safe yield should lie between the two figures of rates of combined draft during the effective lag period immediately preceding commencement of a trough and preceding its disappearance. The difference in specific gravity of the saline and fresh water has a negligible effect on the hydraulic gradient. It is believed that certain concentrations in draft might be utilized to cause limited variations in rate of safe yield.

The total volume of overdraft during any year is equal to the summation of the draft from the shore line to the trough between the time of its commencement and the time of its disappearance. If the overdraft is small and the trough moves only a short distance inland during the season of peak draft, the amount of labor involved in keeping records of extraction between the various positions of the trough and shore line is comparatively small. Knowledge of both, total volume of overdraft, and maximum rate of overdraft are essential in the proper design and operation of a project to relieve the deficiency.

(2) Application of Direct Method to 180-foot Aquifer

There were 660 wells, perforated in the 180-foot aquifer exclusively, that were operated in 1945 for irrigation, municipal and industrial purposes. Reference is made to the description of the alluvial fill in the Salinas Basin hereinbefore set forth in this Chapter and a diagrammatic sketch of the 180-foot aquifer shown on Plate 10. An analysis directly determining ground water movement through the 180-foot aquifer from the data collected in 1945, follows.

(a) Period of Effective Lag

Automatic water stage recorders were installed and maintained on six non-operating wells about four miles apart between Gonzales and the bay shore. Each recorder well was situated more than one-fourth mile from any operating well. An excellent picture of the effective lag period

for a sharp decrease in rate of draft was obtained on the recorders between October 30, and December 11, 1944. Rains during the period from October 30, to November 12, 1944, suddenly stopped, on October 30, all irrigation draft on confined waters in the Pressure Area for the remainder of the year. The average rate of draft changed from about 180 to 40 cubic feet per second on October 30. The rate of draft for industrial, municipal, and domestic uses on the 180-foot aquifer remained fairly constant at about 40 cubic feet per second during November, 1944, then decreased to about 30 cubic feet per second in December. The period of effective lag following the change in rate of draft on October 30, 1944 at a recorder well No. 2-C-148n near the center of the pressure area is shown on Plate 11. All of the recorder wells showed similar lags variously accentuated.

An effective lag period following a sudden large increase in rate of draft on confined waters in the Pressure Area is also shown on Plate 11 at the same recorder well. The rate of draft increased from about 17 to 245 cubic feet per second on April 6, 1946, and then held fairly steady from 245 to 250 cubic feet per second during the following six weeks. The effective lag period for this area appears to be approximately 21 days for both a decrease and an increase in rate of draft.

A difference of two or three days in the period of effective lag in the 180-foot aquifer would result in negligible error in 1945 in the continuous flow equivalent of the draft for the period, because after commencement of the irrigation season changes in average draft were gradual.

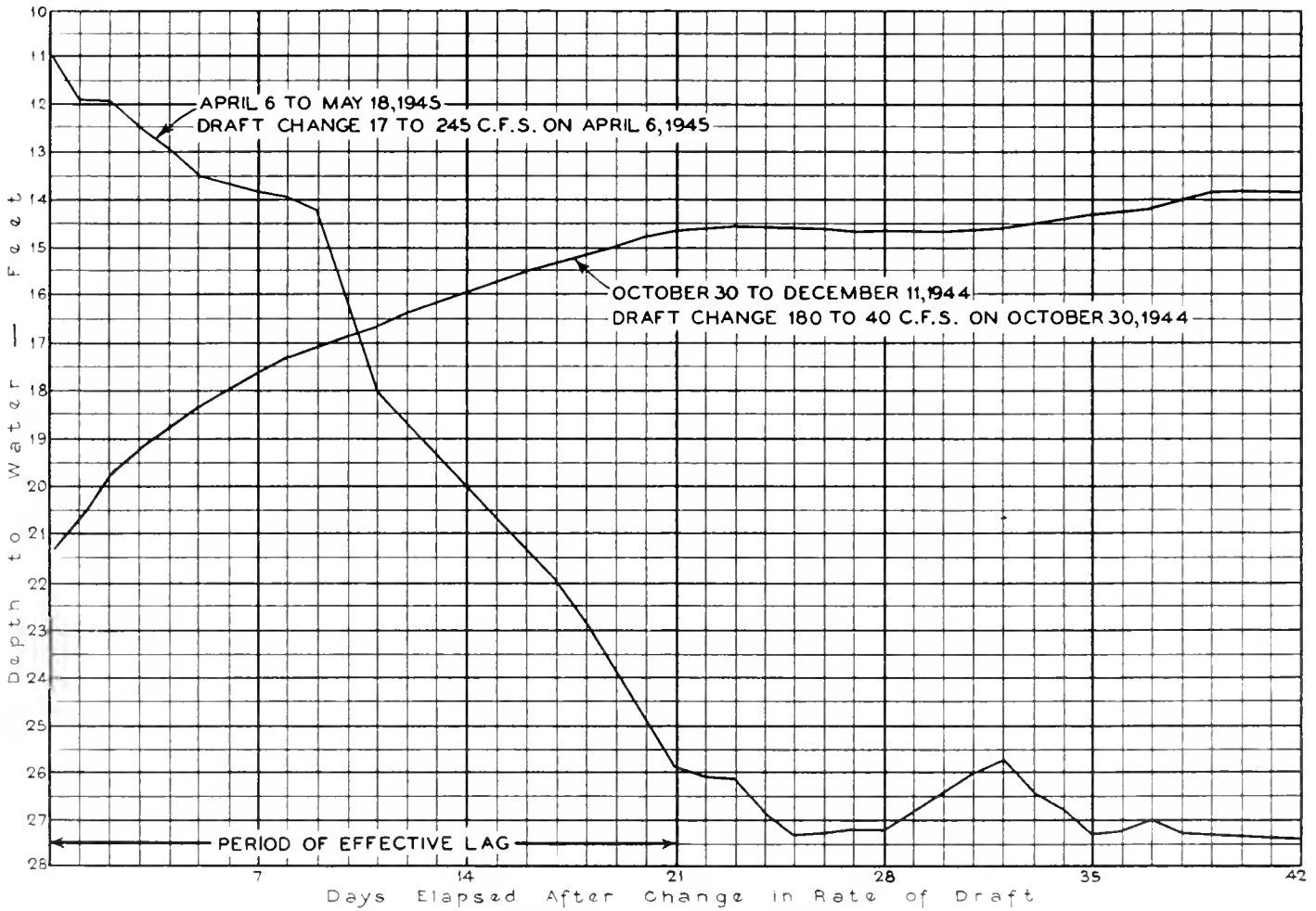
The changes in elevation in the pressure surface near the fountain head and near the ocean canyon, i.e., close to the open ends of the aquifer, were less marked than in the central portion. The accentuation is indicated by the range in fluctuation at the recorder wells in 1945, as set forth in the following tabulation:

Well Number	Location	1945 Range in Fluctuation-feet
4-E-18n	4 miles NW of Gonzales	6.1
4-D-64n	1 mile SW of Spence	13.8
3-D-148n	1 mile North of Spreckels	23.9
2-C-148n	1½ miles SE of Blanco	22.3
2-C-147n	3/4 mile North of Blanco	22.0
1-C-53n	1¼ miles South of River Mouth	11.2

(b) Positions of Trough in Pressure Surface

There was practically no irrigation on Sundays during 1945 in the artichoke belt in the Pressure Area. This belt extends inland from the bay shore for a distance of about five miles. A series of measurements was made every two to four weeks, on Sunday during the irrigation season, of depths to the pressure surface on measuring wells spaced about one-half mile apart extending from the bay shore to a distance of about five miles inland. The measurements were made 14 to 18 hours after the time of cessation of Saturday pumping. The elevations of the pressure surface were spotted on a map accurately showing locations of measuring wells. Lines of equal elevations of the pressure surface were drawn at 1-foot contour intervals. The position of the trough at the time was determined by the line of zero forward movement as revealed by the

PLATE 11



180-FOOT AQUIFER
CONTINOUS RECORDS OF DEPTHS TO WATER
SHOWING
PERIOD OF EFFECTIVE LAG AFTER CHANGES IN RATE OF DRAFT

lines of equal elevation of the pressure surface. The position of the trough on April 29, 1945, shortly after it commenced to form is indicated on Plate 12.

The difference in water elevations inside and outside the casing of an operating well in a pressure area disappears almost instantaneously upon cessation of pumping. The immediate cone of pressure relief was observed to flatten out within a few hours after cessation of pumping through the rapid effect of transmission of hydrostatic pressure. Probably not more than five per cent of the total recovery that would occur through the effective lag period was missed in the measurement series made on Sunday, 14 to 18 hours after cessation of pumping in the artichoke belt. A small correction was made in the elevation of the trough to offset this recovery from the position obtained under operating conditions. A small correction was also made for the effect of change in tidal load on the pressure surface during the series of measurements as indicated by the automatic water stage recorder on well No. 1-C-53n, near the shore line to resolve observations to elevations as of mean sea level.

The position of the trough in the pressure surface, as shown on Plate 12, held fairly steady until the end of May, 1945, under nearly constant draft conditions. Draft gradually increased in the Pressure Area between the end of May from a continuous flow equivalent of about 250 to about 530 cubic feet per second by early in August. The trough commenced to move upstream on June 2 and reached its farthest inland position in 1945 on August 12. The August 12th position of the trough is indicated on Plate 13. The trough position then began to recede downstream and had disappeared prior to November 4, 1945, except for the cone of pressure relief in the vicinity of the operating industrial well between Castroville and Moss Landing.

The average depth of the trough below mean sea level, the estimated distances of its positions, respectively, from the ocean canyon at the north boundary of the confined waters and from the fountain head of the 180-foot aquifer, and the ground water elevation at the fountain head for each measured trough position in 1945 are set forth in the following tabulation:

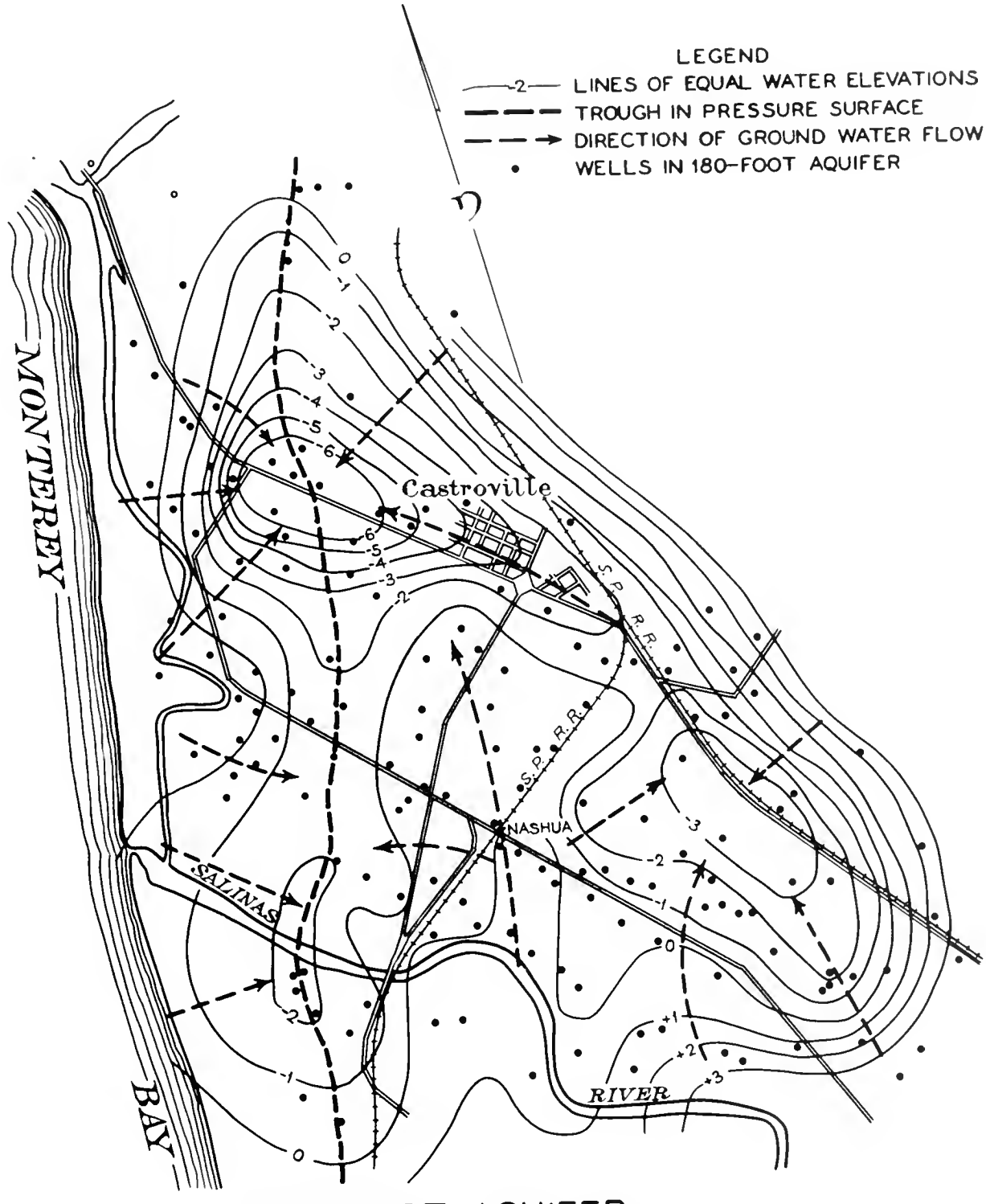
Date of Trough Measurement	Trough Depth Below M.S.L. Feet	Water Levels at Fountain Head--Feet	Distance in Feet	
			To Ocean Canyon	To Fountain Head
April 29	1	100	15,500	132,000
May 20	1.5	100	15,800	131,700
June 3	5	99.5	17,500	130,000
June 24	7	99	18,500	129,000
July 22	11	98.5	20,500	127,000
August 12	12.5	98	22,000	125,500
September 2	9	97.5	19,500	128,000
September 23	5	97	18,800	128,500
October 14	3	97	17,500	130,000
November 4	0	96.4	0	147,500

There was a trough in the pressure surface at the beginning of the effective lag period preceding the measurements of depths to water on November 4, 1945, but it had disappeared sometime between October 14 and November 4.

(c) Relation of Daily Draft to Pressure Surface Fluctuation

During April and May in 1945, the irrigation draft in the Pressure Area occurred almost entirely between the hours of 7:00 A.M. and 6:00 P.M. with one hour out at noon. From June through August the operation was largely continuous during each irrigation for lettuce and celery. Points were obtained on a rating curve during the early part of the season showing the relationship between the daily draft and the daily fluctuation in the pressure surface in the

PLATE 12

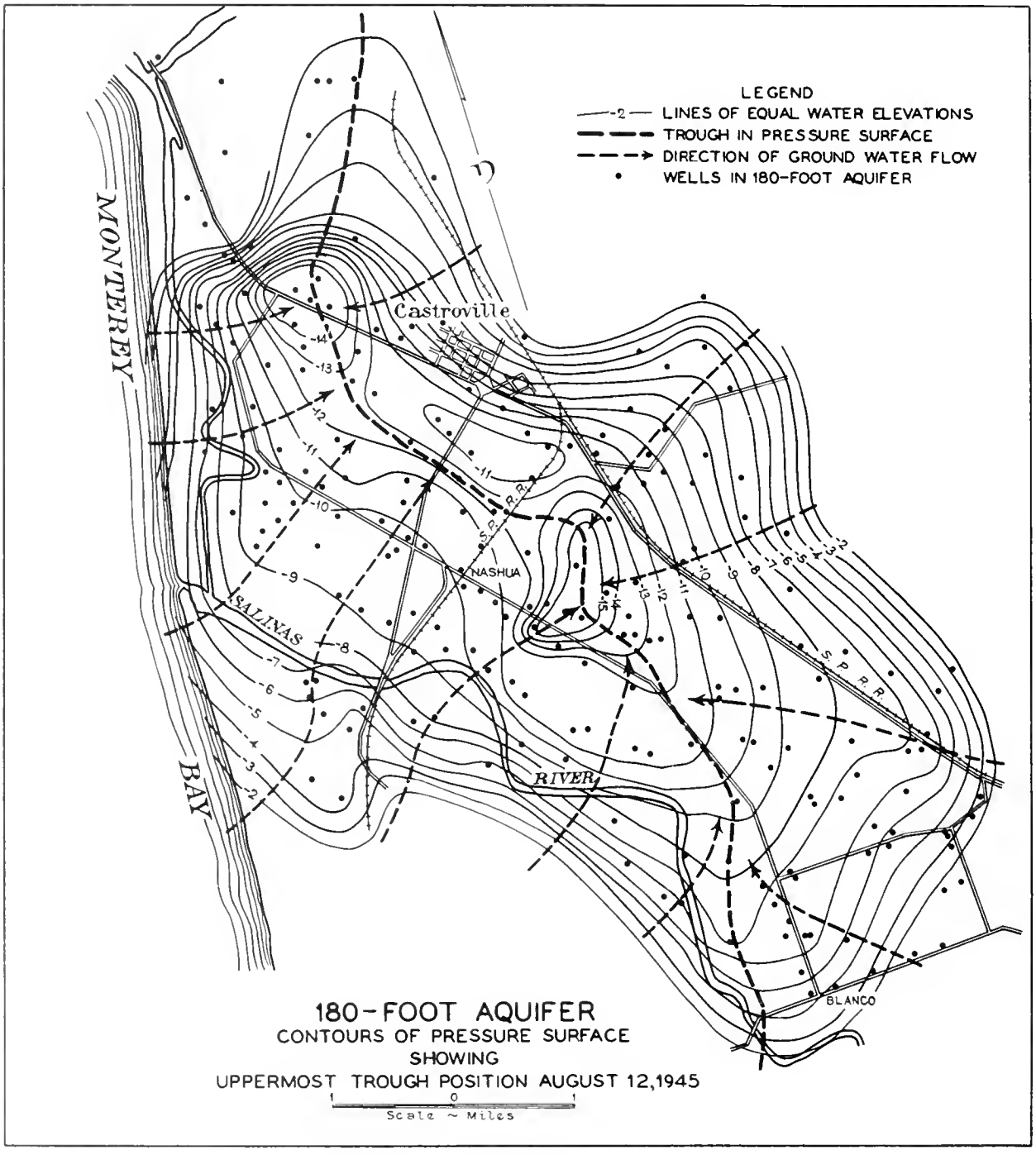


180-FOOT AQUIFER

CONTOURS OF PRESSURE SURFACE
SHOWING
COMMENCEMENT OF TROUGH APRIL 29, 1945

1 0 1
Scale ~ Miles

PLATE 13



180-FOOT AQUIFER
CONTOURS OF PRESSURE SURFACE
SHOWING
UPPERMOST TROUGH POSITION AUGUST 12,1945

1 0 1
Scale ~ Miles

recorder wells. The draft corresponding to the fluctuation was determined by actual count of wells operating during the day of observation. The municipal and industrial demand was obtained from the records of operation. The Bardin recorder well No. 2-C-148n, which is centrally located, appeared to be usable as a control well to establish the relationship between daily fluctuation in the pressure surface and rate of combined draft on the 180-foot aquifer during that portion of the irrigation season when night use of water was unimportant. The observed daily fluctuations at well No. 2-C-148n during four days in April, 1945, on the 180-foot aquifer were as follows:

Date	Pressure Surface Fluctuation-feet	Combined 10-hour Rate of Draft-C.F.S.	Continuous Flow Equivalent-C.F.S.
April 8	0.35	123	51
April 18	2.30	575	239
April 19	3.84	850	354
April 27	3.05	718	299

The above observations were used to establish curves of the relationship of combined 10-hour rate of draft of all pumping from the 180-foot aquifer and the continuous flow equivalent thereof to daily fluctuation in the pressure surface as shown on Plate 14. The daily fluctuations at recorder well No. 2-C-148n and the corresponding rates of total draft obtained from Plate 14 during each 3-week period of effective lag preceding the first three measured positions of the trough in the pressure surfece on April 29, May 20, and June 3, 1945, are set forth in Table 3 of Appendix A. A summary of the results follows:

Date of Trough Measurement	Effective Lag Period	Average Draft-Cu. Ft. per Sec. 10-hour Rate	Continuous Flow
April 29, 1945	April 8 to 28	588	245
May 20, 1945	April 29 to May 19	597	250
June 3, 1945	May 13 to June 2	665	275

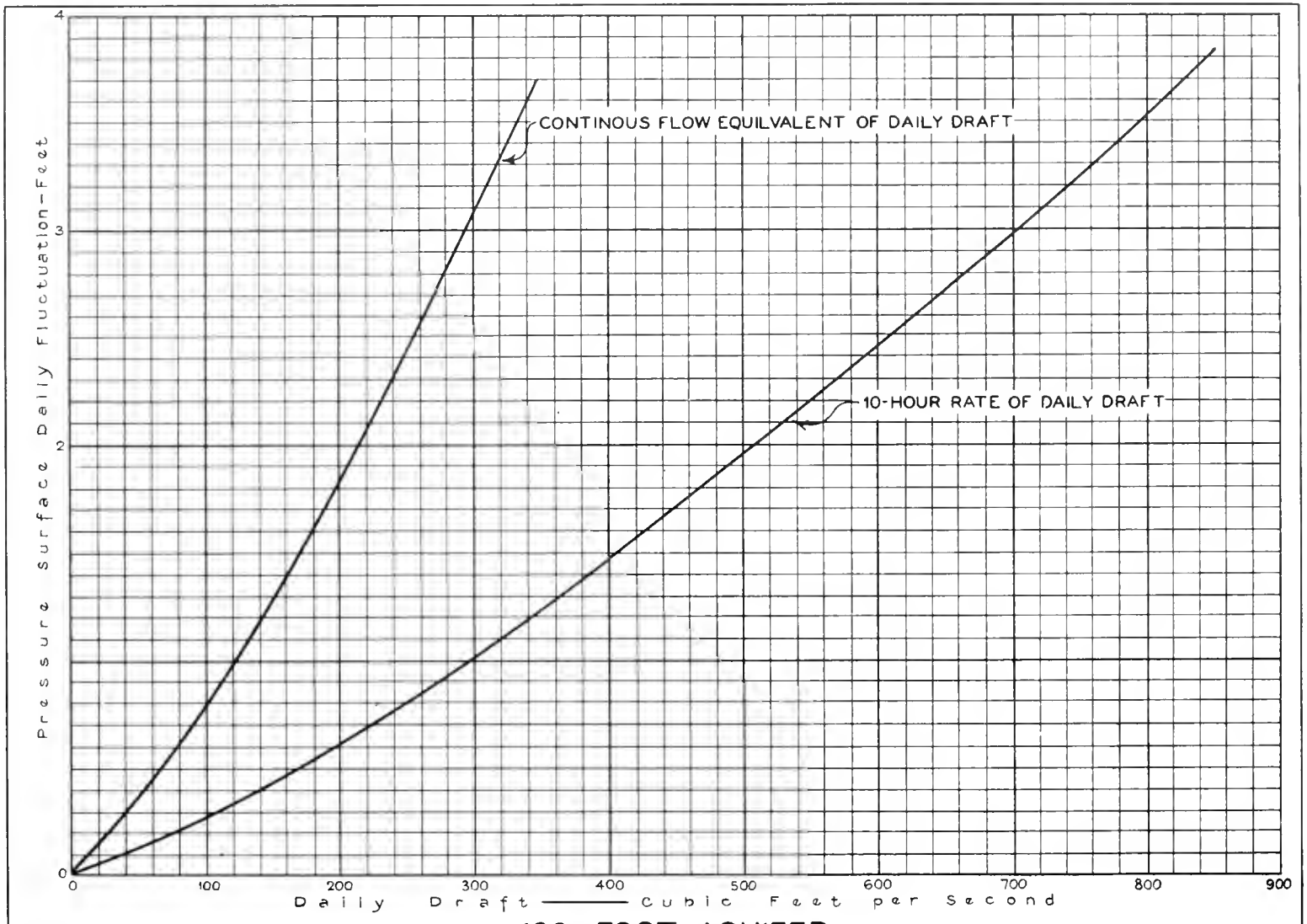
Observations were made of the pumping installations operated and tracts served with water between the bay shore end the trough in the pressure surface. The estimated continuous flow equivalent of combined draft between the bay shore and the trough during the effective lag period preceding each measured trough position in 1945 follows:

Date of Trough Measurement	Effective Lag Period	Continuous Flow Equivalent of Draft Cubic feet per Second
April 29	April 8-28	7
May 20	April 29-May 19	10
June 3	May 13-June 2	25
June 24	June 3-23	40
July 22	July 1-21	55
August 12	July 22-August 11	55
September 2	August 12-September 1	45
September 23	September 2-22	25
October 14	September 23-October 13	15
November 4	October 14-November 4	3

(d) Coefficient of Permeability and Cross-section of Aquifer

The combined effect of coefficient of permeability and area of cross-section of the 180-foot aquifer on the bay side of the trough in the pressure surface during each of the measured

PLATE 14



180-FOOT AQUIFER
RATING CURVES
SHOWING
DAILY DRAFT-PRESSURE SURFACE FLUCTUATION RELATIONSHIP

positions of the trough was calculated by use of the formula $PA = \frac{Q}{h} l$ where

P = average coefficient of permeability;

A = average net area of cross-section of aquifer;

Q = continuous flow equivalent of the combined draft on bay side of trough during the effective lag period in cubic feet per second;

l = average distance from trough to ocean canyon in feet;

h = average depth of trough below mean sea level in feet.

The calculated value of PA on the bay side of the trough was fairly constant for the various trough positions at near 100,000.

The above formula was also used to calculate the average value of PA between the trough in the pressure surface and the fountain head of the 180-foot aquifer during the first three measured trough positions in 1945, when reliable information was obtained on total draft. The observed continuous flow equivalent to draft on the bay side of the trough was subtracted from the continuous flow equivalent of total draft obtained from Plate 14 to evaluate Q on the inland side of the trough during each of the three effective lag periods. The value of h was determined by adding the depth of the trough below mean sea level to the ground water elevation at the fountain head. The distance between the Gonzales River Road, which is assumed to be the approximate position of the fountain head of the 180-foot aquifer, and the measured trough position was taken as the value of l. The calculated values of PA on the inland side for the first three measured trough positions are shown in the following tabulation:

Date of Trough Measurement	Continuous Flow Draft Q in C.F.S.	Average Slope Pressure Surface h/l	Coefficient of Permeability and Area of Cross-section Product of PA
April 29	238	101/132,000	310,000
May 20	240	101.5/131,700	311,000
June 3	250	104.5/130,000	311,000

It appears probable from the above tabulation, that the product of PA on the inland side of the trough would not vary much from 310,000 for the various upstream positions of the trough in 1945, which shifted within a range of 4500 feet between June 3 and October 14. There were no unusual draft concentrations between June 3 and October 14. The observed value of Q and calculated value of PA automatically include the net effect of lateral inflow to and escape from the 180-foot aquifer along its course, neglecting the slight discrepancy due to the fact that the Q_o is observed from pumpage while the Q_i is calculated. The entire escape and inflow is in Q_i.

(e) Draft on 180-foot Aquifer in 1945

Based on the assumption that the value of PA remained constant at 310,000 on the inland side of the trough between June 3 and November 4, 1945, the calculated values of Q_i, which represent continuous flow equivalents of draft on the inland side of the trough during the respective periods of effective lag, are set forth in the following tabulation:

Effective Lag Period	Average Slope Pressure Surface h/l	Continuous Flow Equivalent of Draft on Inland Side of Trough Q in Cu.Ft./Sec.
June 3-23	106/129,000	255
July 1-21	109.5/127,000	265
July 22-August 11	110.5/125,500	275
August 12-September 1	106.5/128,000	260
September 2-22	102/128,500	245
September 23-October 13	100/130,000	240
October 13-November 3	96.4/147,500	185*

* It is probable that the continuous flow equivalent of draft during the effective lag period between October 13 and November 3 was somewhat less than 203 cubic feet per second calculated for a 310,000 valuation of PA. Since the trough had disappeared prior to November 4, there was probably outflow to the bay from the 180-foot aquifer during the latter part of the period under conditions of a materially reduced value of PA to about 100,000. Rains at the end of October stopped all irrigation draft in the Pressure Area during the last three days of the period, consequently a PA value of 310,000 was assumed for 18 days and 100,000 for the last three days of the period to obtain the above calculated average rate of 185 cubic feet per second.

The foregoing calculated drafts on the inland side of the trough when combined with draft estimated from direct observations on the bay side provide an independent approach to evaluation of total extractions from the 180-foot aquifer during the 1945 irrigation season. A separate estimate has been made of draft on the 180-foot aquifer for municipel and industrial uses, which permits a segregation of pumping for irrigation purposes from combined extractions. These results are set forth in the following tabulation:

		Continuous Flow Equivalent of Draft--C.F.S.				
Period in 1945	Days	Bay Side of Trough	Inland Side of Trough	Total	Municipel and Industrial	Irrigation
4/8-4/28	21	7	238	245	15	230
4/29-5/19	21	10	240	250	20	230
5/20-6/2	14	25	250	275	20	255
6/3-6/23	21	40	255	295	25	270
6/24-7/21	28	55	265	320	25	295
7/22-8/11	21	55	275	330	25	305
8/12-9/1	21	45	260	305	40	265
9/2-9/22	21	25	245	270	45	225
9/23-10/13	21	15	240	255	40	215
10/14-11/3	21	3	185	188	40	148
4/8-11/3	210	29	245	274	29	245

The above irrigation draft is equivalent to approximately 103,000 acre-feet during the 210-day period.

The estimated pumping from the 400-foot aquifer in 1945 for irrigation purposes in the Pressure Area was about four per cent of that from the 180-foot aquifer, or about 10 cubic feet per second continuous flow equivalent during the above 210-day period. Total use was about 107,000 acre-feet when combined with the above table. The calculated total use of water from both aquifers for irrigation purposes in 1945 on 50,500 acres of irrigated land in the Pressure Area was at an average rate of one cubic foot per second to about 195 acres. This is equivalent to combined extractions of 107,000 acre-feet, as compared with an estimated use of 104,000 acre-feet in 1944, determined by an independent approach hereafter set forth in Appendix C. The estimated use of water in 1944 as hereinbefore calculated from consumption of electric energy for agricultural use in the Pressure Area was about 103,000 acre-feet. Results by method outlined here approximately check those from other methods.

(f) Velocity of Ground Water Flow

The available well logs that have been identified in the Pressure Area, which have been set forth in Bulletin 52A, enable a determination of approximate thickness of the water-bearing formations in the 180-foot aquifer. As previously stated, the logs show a variation in thickness from 35 to 179 feet with an average of about 100 feet.

The blue clay zone embraces a gross area of about 76,000 acres over a distance of approximately 26 miles between Gonzales and the bay shore. This indicates an average width of the area of confined water of about 4.6 miles, which, when multiplied by 100 feet average thickness, indicates an average gross area of cross-section of the 180-foot aquifer of approximately 56 acres.

Separate ascertainment of average net area of cross-section of the aquifer and velocity of flow are unnecessary under the foregoing approach to determination of rates of safe yield and overdraft. However, separate calculation of these items, with an average porosity of the water-bearing formation assumed to be 33-1/3 per cent, has some value for comperative purposes with results obtained in other areas by use of different methods.

With an assumed average porosity of 33-1/3 per cent, the average net area of cross-section of the aquifer would be approximately 18.7 acres. The calculated average velocities on both sides of the trough in the pressure surface under prevailing hydraulic gradients for various measured positions thereof during the 1945 irrigation season are set forth in the following tabulation:

Period in 1945	Continuous Flow Equivalent of Draft--C.F.S.		Average Velocity Feet per Day	
	Bay Side of Trough	Inland Side of Trough	Bay Side of Trough	Inland Side of Trough
4/8-4/28	7	238	0.7	25
4/29-5/19	10	240	1.1	25
5/20-6/2	25	250	2.6	26
6/3-6/23	40	255	4.2	27
6/24-7/21	55	265	6	28
7/22-8/11	55	275	6	29
8/12-9/1	45	260	5	28
9/2-9/22	25	245	2.6	26
9/23-10/13	15	240	1.6	25
10/14-11/3	3	185	.3	20
4/8-11/3	29	245	3	26

The calculated velocities set forth in the foregoing tabulation are average velocities as distinguished from effective velocities. The standard coefficient of permeability is based on effective velocity and effective porosity. The above calculated average velocity on the bay side of the trough, during the period of time when there was inland movement of water from the bay in 1945, indicates a possible marine intrusion encroachment of about 200 yards during the season. This is an approximate check on the movement of the fringe of contamination during 1945 in the northerly portion of the aquifer as determined by analyses of water samples hereafter described in Chapter VII.

Safe Yield and Overdraft - 180-foot Aquifer

The rate of safe yield of the 180-foot aquifer, as controlled by possibilities of marine intrusion, has been computed from the foregoing evaluation of the average combined effect on the inland side of the trough in the pressure surface of the coefficient of permeability and

area of cross-section of the formation. The trough position for rate of safe yield was taken at the lowermost wells near the bay shore. Under such conditions the slope of the hydraulic gradient will approximate 100/135,000. The calculated rate of safe yield (Q) for such a slope with PA equal to 310,000 is approximately 230 cubic feet per second.

The maximum 3-week average total draft on the 180-foot aquifer in 1945 of about 330 cubic feet per second exceeded the rate of safe yield by about 100 cubic feet per second, which was actual overdraft. As the rate of draft increases, the hydraulic gradient of the pressure surface and the yield of the aquifer also increase. A rate of total draft of 100 cubic feet per second in excess of rate of safe yield appears to cause an increase in flow of nearly 20 per cent above the safe yield rate. The average rate of apparent overdraft during that 3-week period was thus approximately 55 cubic feet per second even though the rate of safe yield was exceeded by about 100 cubic feet per second. Inducement of greater flow through the aquifer by means of overdraft attended with change in place of extractions offers some possibility of enhancement of water supply in the Pressure Area.

Definitions of "actual overdraft" and "apparent overdraft" are necessary to avoid confusion in an analysis of overdraft in the Pressure Area. As herein used these terms are defined as follows:

(1) Actual overdraft is the cumulative amount of the excess in rate of total draft over and above the rate of safe yield of the aquifer during any year.

(2) Apparent overdraft is the cumulative amount of the excess in rate of total draft over and above the rate of downstream flow in the aquifer during any year.

The cumulative amount of draft on the bay side of the trough in the pressure surface during 1945 is thus a measure of the apparent overdraft on the 180-foot aquifer in that year. The continuous flow equivalent of such draft, as hereinbefore set forth was about 29 cubic feet per second during a 210-day period. This is equivalent to an apparent overdraft in 1945 of approximately 12,000 acre-feet. The rate of apparent overdraft in 1945 varied between zero and about 55 cubic feet per second.

The cumulative amount of the excess in rate of total draft over and above the rate of safe yield of the 180-foot aquifer in 1945 was approximately 10,300 second foot-days between April 8 and October 13. This is equivalent to an actual overdraft in 1945 of approximately 20,000 acre-feet. The rate of actual overdraft in 1945 varied between zero and about 100 cubic feet per second. The actual overdraft in 1945, after October 13 was negligible.

Inflow-Outflow from and to Bay

There has probably never been any ground water inflow to the 400-foot aquifer from Monterey Bay because it appears that the pressure surface of this aquifer has never been depressed below mean sea level. The first well near the bay shore in the 400-foot aquifer was drilled in 1945. The elevation of the pressure surface in September 1945, was about 2.5 feet above mean sea level. A total of only 37 wells in the 400-foot aquifer does not provide information comparable to that on the 180-foot aquifer. The amount of mutual interference from a limited number

of wells indicates the ground water movement is materially less than in the 180-foot aquifer.

(1) 180-foot Aquifer in 1944-45

Observations of the behavior and positions of the trough in the pressure surface of the 180-foot aquifer during the period from October 1, 1944 to September 30, 1945, provide a basis for calculation of outflow and inflow to and from the bay in this aquifer. Series of measurements of depths to water on 44 wells near the bay shore on October 1, 15, and 29, in 1944, show substantially the same trough positions and depths that prevailed during October 1945. Sudden cessation of irrigation in the Pressure Area occurred on October 30, in both 1944 and 1945, and the trough in the pressure surface disappeared at approximately the same time in both years.

An appreciable trough in the pressure surface prevailed during approximately 27 out of 52 weeks between October 1, 1944 and September 30, 1945. The water levels in the Salinas delta were at or near mean sea level for about five weeks during the seasonal year with little or no ground water movement near the bay shore. Water levels were two to four feet above mean sea level near the shore during the remaining 20 weeks of the seasonal year. It is assumed that the approximate value of 100,000, previously determined as the combined effect of coefficient of permeability and area of cross-section, on the bay side of the trough governs the inflow and outflow from and to the bay. The average slope of the pressure surface during the 20-week period of outflow approximated 100/147,500. The calculated average rate of outflow is about 68 cubic feet per second, which is equivalent to a total outflow for the 20-week period of about 19,000 acre-feet.

The inflow during the 27-week period when a trough prevailed in the pressure surface of the 180-foot aquifer is equal to the apparent overdraft during the seasonal year 1944-45. Apparent overdraft during the irrigation season in 1945 has previously been evaluated as approximately 12,000 acre-feet. Apparent overdraft in October, 1944 was substantially the same as in October, 1945. The ground water inflow from the bay to the 180-foot aquifer during the seasonal year 1944-45 is thus estimated to be about 12,000 acre-feet.

(2) Perched Water and 400-foot Aquifer in 1944-45

Ground water movement of the perched water table is largely intercepted by surface drains in the delta area, which flow is susceptible of direct measurement as surface outflow. The perched water table has an average elevation of about four feet above mean sea level on approximately 500 acres near the bay shore, which area drains directly into the bay or its backwater. The application of irrigation water on this area in 1944-45 was equal to approximately 1.6 feet in depth and the precipitation thereon was about 1.3 feet. The estimated annual consumption on the area is about 1.7 feet. There was no appreciable difference in the perched water table between the beginning and end of the seasonal year. There was a small amount of surface runoff from rainfall on the area early in November 1944. It therefore appears that the perched water outflow in 1944-45, as underground drainage direct to the bay or its backwater, was somewhat less than 600 acre-feet. Inflow was not possible from the bay to the perched water zone in 1944-45.

Due to scanty information available on the 400-foot aquifer and other water-bearing formations, if any, in addition to the 180-foot aquifer and perched water, the outflow therefrom has been computed as a differential. The total consumptive use on the alluvial fill in 1944-45 has previously been estimated to be 433,000 acre-feet. The total decrement in ground water storage for the year has been estimated as 50,000 acre-feet, which indicates a total retention of 383,000 acre-feet. The total inflow to the alluvium in 1944-45 has been estimated as 745,000 acre-feet and all outflow except ground water, has been calculated as 335,000 acre-feet, which indicatea a retention of 410,000 acre-feet less ground water outflow. The difference between 410,000 and 383,000 acre-feet is a measure of total ground water outflow. The outflow from the 180-foot aquifer and perched water has been calculated to be in the order of 19,000 acre-feet. The estimated outflow from the 400-foot aquifer is included in the differential of 8,000 acre-feet.

Disposal of Pressure Area Summer Draft

The precipitation during the irrigation season in 1944 and 1945, was respectively 2.03 inches and 0.77 inches. An approximate check may be made of the disposition of the total draft in the Pressure Area during the irrigation season by assuming that the perched water increment between April 1 and November 1 is equal to the summer precipitation. Four well points to perched water in the northerly portion of the Pressure Area indicated an average rise in the perched water table in this section of about 0.5 foot during the irrigation season in each 1944 and 1945.

The relation of summer consumptive uses in 1944 and 1945 to normal summer consumption has been calculated by Mr. Harry F. Blaney, respectively, as 98.7 and 100.3 per cent, as hereafter set forth in Appendix C. The irrigated acreage in the Pressure Area in 1945 was approximately one per cent greater than in 1944. The ratio of irrigated acreages in 1945 crop classifications is assumed to be the same as that in 1944. It is further assumed that none of the pumping draft went to supply any of the consumption on irrigable dry-farm and grass land, waste land and roads and railroads. The estimated diaposal of total pumping draft in the Pressure Area during the two irrigation (summer) seasons is set forth in the following tabulation:

Item	Disposal in Acre-Feet 1944	1945
Irrigated crop consumption	49,000	50,500
Native vegetation consumption	25,000	25,500
Miscellaneous consumption	12,000	12,000
Irrigation return and sewage	16,000	17,000
Return to free ground water -- Quail Creek area	5,000	5,000
Ground water outflow to perched water	500	500
Return to 180-foot aquifer	8,500	9,500
Totals	116,000	120,000

The estimated amounts of water pumped for all purposes in the Pressure Area during the two summer seasons are set forth in the following tabulation:

Purpose	Acre-Feet Pumped 1944	1945
Irrigation use	104,000	107,000
Domestic, Municipal and Industrial Use	12,000	13,000
Totals	116,000	120,000

The above estimated return to the 180-foot aquifer is based on the calculated amount of contamination from perched water. It is probable that this contamination has largely occurred within the last ten years. If the contamination has occurred over a 10-year period, the amount thereof would necessitate an average annual rate of about 5,000 acre-feet. It is probably occurring at an accelerated rate. A uniform rate of increase has been assumed from 500 acre-feet in 1936 to 9,500 acre-feet in 1945.

CHAPTER VII

QUALITY OF WATER

The ground water at any point in the Salinas Valley may be a mixture of many waters, each of which may differ materially in concentration of solubles and constituents therein. As previously stated, approximately 97 per cent of the estimated total percolation from stream flow in the Salinas Valley, during the 16-year period from 1929-30 to 1944-45, inclusive, occurred in the area south of Gonzales, where about 70 per cent of the runoff normally comes from the Santa Lucia Range below Paso Robles. Waters emanating from the Santa Lucia Range are of good quality, whereas those coming from the Diablo Range have comparatively high concentration of solubles.

After the percolate reaches the water table it joins in the ground water flow, which moves slowly across the basin and receives contributions from precipitation, irrigation water return, sewage effluent and stream flow percolation. Precipitation is practically free of solubles. The irrigation water in the basin consists almost entirely of extractions from ground water, and the quality varies depending on the location and depth of well. The unconsumed portion of irrigation water which becomes charged with natural soil solubles and applied fertilizers, largely returns to the pumping zone in the areas of free ground water. Sewage effluent and percolation from cesspools are usually saline with high nitrate concentration.

The composition of ground water may differ materially from the result that would be obtained from a simple mixture of samples from the various sources of supply. Modifications of the solubles in percolate moving through alluvium may result from base exchange between the water and the minerals in the sediment. This type of change involves only the positive ions and is dependent on the presence of base-exchange material in the alluvial fill through which the ground water moves. The cations differ widely in ability to replace each other with calcium, potassium and magnesium, having higher base-exchange activities than sodium.

Another type of modification that may occur is that which affects only the proportions between the anions, such as changes in sulphate and bicarbonate content due to processes of sulphate reduction and substitution of carbonic or other weak acid radicals. This type of modification and the above mentioned base exchanges do not effect changes in concentration because ionic balance is maintained. Only solution and precipitation result in gain or loss of total solubles.

Vast alterations in concentration of solubles in ground water may occur under certain conditions. Where marine intrusion occurs in alluvium containing anhydrite the calcium and sulphate content of solubles may be tremendously increased. Marine intrusion may cause precipitation of calcium carbonate from ground waters where the pH is high and an accompanying sulphate reduction may occur.

Due to the many complexities introduced through modifications in composition and alterations in concentration of solubles, identification of sources of ground water and of contaminants is not possible from direct comparison of constituents therein as determined by mineral analysis. Various hydrological and geochemical considerations are involved in the interpretation.

Collection of Samples and Analytical Data

All samples of water collected during the investigation were tested in the field with a resistometer connected with a standard United States Bureau of Soils testing cup to determine reletive concentrations of electrolytes in the total solubles. The resistometer, which is an adaptation of the Wheatstone bridge, was rated from complete analyses of 108 samples in the laboratory at Berkeley of the Division of Plant Nutrition, Agricultural Experiment Station, University of California College of Agriculture. The term "complete analysis", as used herein, means one in which at least three negative ions and enough positive ions were determined to permit the computation of per cent sodium. All samples collected for complete analysis, 119 during the investigation, were submitted through the Monterey County Farm Advisor to the laboratory at Berkeley.

Chloride is a major ion in a contaminant having its source as sea water. Chloride concentration is not affected by the above mentioned processes of modification. Chloride is also an important ion in perched water, which is a source of contamination of waters in the pumping zone in the Pressure Area. After types of water in the various localities were ascertained through complete analysis, general reconnaissance of quality of water in the Pressure Area was made by partial analyses, which involved titration of samples for chlorides and approximate determination of total solubles by the resistometer test. The partial analyses were supplemented by complete analyses in the borderline samples of doubtful quality.

Samples of water obtained from wells were generally collected under operating conditions after continuous pumping for more than two hours. Where liquid fertilizer was being injected in the discharge pipe and non-scale forming drip into the casing, these were shut off for at least ten minutes prior to taking the sample. In a few instances samples were taken from non-operating wells and from well points to perched water by means of a hose-reel thief sampler. The quality of water was tested in a few wells near the bay shore, after being idle over the winter, at different depths by means of a portable electrode and the above mentioned resistometer.

The Division of Water Resources caused ten samples of water from surface streams in the Salinas Basin to be collected in 1941 for complete analysis at the University of Californie Citrus Experiment Station at Riverside by Chemist S. M. Brown. Some additional samples were collected in 1944 from surface drains and streams for complete analysis to supplement existing information. Full use has been made of former analyses of surface waters in the Salinas Basin as set forth in Division of Water Resources Bulletin 29, United States Geological Survey Water Supply Papers 89 and 237, Technical Bulletin 746 of the United States Department of Agriculture, and Special Bulletin 63 of the State of California Department of Public Health.

All information on quality of water in the Salinas Basin in the files of the Monterey County Farm Advisor was made available by Mr. A. A. Tavernetti. Various landowners in the basin supplied copies of reports of water analyses from commercial laboratories. The reports on 26 analyses by the Rubidoux Laboratory in Riverside made for the Division of Water Resources in 1932 and for the Emergency Rubber Project at Salinas in 1942 are available for comparative purposes.

All basic data obtained on quality of waters in the Salinas Basin have been set forth in Bulletin 52A.

Interpretation of Analyses

The temperature of the water at a well under operating conditions in the Pressure Area is an indicator of the depth of the well and the aquifer in which the casing is perforated. The temperature of the water in the 180-foot aquifer varies from about 64°F. to 66°F. The temperature of the water in the 400-foot aquifer runs uniformly at about 70°F to 71°F. Wells perforated in both aquifers have waters with temperatures between 66°F. and 70°F. The temperature of the waters in four wells 600 to 800 feet deep in the Moss Landing area is about 78°F.

The concentration of constituents in the solubles or reacting value is expressed in terms of milligram equivalents per liter (M.E./L.), with the exception of elemental boron, in all complete analyses herein set forth. Boron is expressed in terms of parts per million (p.p.m.) The unit M.E./L. is equivalent to that of equivalents per million (e.p.m.) when the specific gravity of the sample is unity. For practical purposes the unit M.E/L. may be considered identical with the unit e.p.m. in waters suitable for irrigation purposes. Concentrations expressed in e.p.m. may be multiplied by the equivelent weight of the ion to convert to parts per million (p.p.m. The equivalent weight is obtained by dividing the atomic or molecular weight by the valence. The approximate conversion factors to change expressions herein in M.E./L. to p.p.m. follow:

Constituent	Equivelent Weight	Constituent	Equivalent Weight
Calcium (Ca)	20	Carbonate (CO_3)	30
Magnesium (Mg)	12.2	Bicarbonate (HCO_3)	61
Sodium (Na)	23	Chloride (Cl)	35.5
Potassium (K)	39.1	Sulphate (SO_4)	48
		Nitrate (NO_3)	62

(1) Total Solubles

The electrical resistance of a water sample in a standard United States Bureau of Soils testing-cup by a resistometer is expressed in ohms at the observed temperature of the sample. This value has been converted to approximate total solubles expressed as parts per million (p.p.m).

It was observed in the Castroville Area that the upper limit of safe use for irrigation from the standpoint of totel solubles was about 1300 p.p.m. Total solubles of 1300 p.p.m. in the 180-foot aquifer near the bay shore indicate a chloride concentretion of approximately 14 M.E./L. There is an excellent drainage system generally covering this area and the precipitation is normally adequate to cause a leaching of salts from the top-soil during the winter season.

The upper limit for safe use for irrigetion as to total solubles in the water in the Salinas area appears to be about 1700 p.p.m. This represents in this area a chloride concentration of ebout nine M.E./L. and approximately an equal concentration of sulphates. Heavy soils with slow drainage predominate in this area and the precipitation is normally inadequate to cause leaching of salt concentrations from the top-soil.

Total solubles in excess of about 1600 p.p.m. in the San Ardo Valley appear to be toxic to vegeteble truck crops. The water there is of the sulphete type and tctal solubles in the order of 1600 p.p.m. contain in this area a sulphate concentration of about 16 M.E./L.

It was noted that irrigation water containing total solubles in excess of about 1400 p.p.m. in the San Lorenzo delta in the King City area was injurious to crops. In this area, total solubles in excess of 1400 p.p.m. will usually contain in excess of 2.0 p.p.m. of elemental boron. This is the only area in the alluvial fill in the Salinas Basin where toxic amounts of boron have been found. Samples of water analyzed from all other areas in the basin show boron concentrations materially less than 0.5 p.p.m. Total solubles of 1400 p.p.m. in waters in the southern portion of the San Lorenzo delta are also apt to contain chloride concentrations in excess of 10 M.E./L. The waters in the eastern portion of the delta contain high concentrations of sulphates.

No injurious concentration of solubles was found any place in the Arroyo Seco Cone, and Forebay and East Side Areas. There appears to be a tendency in recent years toward a progressive accumulation of solubles in the Forebay Area due to inadequate movement of ground water therefrom as compared with the amount of return to the pumping zone of unconsumed irrigation water.

(2) Per Cent Sodium

Per cent sodium is calculated by dividing the sum of milligram equivalents of calcium, magnesium and sodium into the amount of sodium and multiplying by 100. So far as is known, sodium is not one of the elements essential to plant growth. Whenever total solubles are high, the dominant positive ion is usually sodium. A high per cent sodium in the soil solution and applied irrigation water operates against maintenance of good tilth and permeability in the soil, and decreases the absorption of water by plant roots through osmotic effects of its salts. High concentrations of sodium in irrigation waters result in reactions of base exchange in the soil whereby calcium and magnesium are replaced by sodium and the soil tends to become gelatinous.

(3) Calcium and Magnesium

Calcium and magnesium salts make up the hardness group that is a particularly important consideration in water utilization for domestic, municipal and industrial purposes. Calcium is usually not troublesome in water quality for irrigation purposes due to its low solubility in combination with carbonate, bicarbonate and sulphate. Magnesium sulphate however is highly soluble and where it occurs in excessive concentrations on the east side of the Upper Valley Area it reduces the rate of osmosis in the plant roots. Separate determination of these constituents is helpful in a diagnosis of contaminants.

(4) Chloride and Sulphate

The various concentrations of chlorides and sulphates that appear injurious to plant growth in different areas in the Salinas Basin have been discussed above under "Total Solubles". Whereas sulphates are essential to plant growth, it is doubtful that chlorides are in any way useful. Combined concentrations in irrigation water of chlorides and sulphates in excess of 20 M.E./L. appears to be harmful to sensitive crop plants.

(5) Carbonate and Bicarbonate

The harmful effects of black alkali containing the carbonate-bicarbonate constituent is generally known. The injury is probably attributable to sodium, rather than carbonate-bicarbonate, and sodium concentration is just as harmful when it occurs with other anions. Even where

the carbonate-bicarbonate complex comprises almost all the anions, the water is probably safe for irrigation use if the per cent sodium is low.

(b) Boron

A small amount of boron in the soil solution is essential to plant growth. Concentrations of elemental boron in irrigation water of less than 1.0 p.p.m. may be injurious to sensitive crop plants such as beans, vetch, and walnuts that generally are grown in the Upper Valley Area. Sugar beets and alfalfa appear to be tolerant of concentrations above 3.0 p.p.m. in the San Lorenzo delta, which is the only area in the Salinas Basin where toxic amounts of boron have been found in the surface inflow and ground water. Dilution from Salinas River percolation reduces the boron concentration in the westerly portion of the delta.

Surface Streams

The amount of solubles in the surface flow of streams in the Salinas Basin varies widely with the regimen of flow and the time of occurrence of flow. Analysis of a single sample may not be indicative of average solubles. This is illustrated by results of analyses of samples taken from the Salinas River at the San Ardo, Soledad and Spreckels Bridges in 1941, at the time of minimum flow on August 28 and during the first winter flood on December 29. The total anions in the solubles at the times of collection of the two series of samples are shown in the following tabulation.

	Total Anions - M.E./L.	
Place in Salinas River	Aug. 28, 1941	Dec. 29, 1941
Under San Ardo Bridge	6.70	2.86
Under Soledad Bridge	12.92	4.09
Under Spreckels Bridge	14.20	5.66

The foregoing tabulation also shows an increment in solubles during the course of flow from San Ardo toward Monterey Bay. The United States Geological Survey in cooperation with the Division of Water Resources (then State Department of Engineering), between December 1907 and December 1908, collected and analyzed 30 to 37 samples at regular intervals at each of five points on surface streams in the Salinas Basin. The range and average of total anions in these series of samples are shown in the following tabulation:

	Total Anions - M.E./L.		
Stream and Location	Minimum	Maximum	Average
Salinas River near Paso Robles	4.7	9.4	7.8
Estrella Creek near San Miguel	12.9	23.6	18.3
Arroyo Seco near Soledad	2.4	7.2	4.7
San Antonio River near Bradley	3.9	12.5	6.3
Nacimiento River near San Miguel	3.2	6.6	4.8

The foregoing tabulation also shows low average solubles in the waters of the Arroyo Seco and San Antonio and Nacimiento Rivers which have their sources on the Santa Luica Range as compared with Estrella Creek, which heads on the Diablo Range. Most of the flow of the Salinas River near Paso Robles emanates from the Santa Lucia Range.

The quality of the waters in the Salinas River above Gonzales is most important during two different periods in the year when greatest contribution to ground water occurs. A rapid rate of percolation occurs from the first river flow during the runoff season following cessation of fall irrigation when prevailing water levels in the free ground water areas are near the low point for the year. A rapid rate of percolation from the river also occurs after the commencement of the irrigation season on or about the first of April until the river flow fails. Fortunately the early and late flows in the Salinas River are usually entirely supplied by tributaries heading on the Santa Lucia Range where the precipitation is approximately twice that on the Diablo Range. The east side streams between Metz and Paso Robles ordinarily do not commence to flow during the winter season until substantially full recharge of ground water has occurred in the areas supplied by river percolation. Only that portion of ground water formations lying east of the Salinas River influence between Metz and San Ardo usually receives replenishment from surface waters containing high concentration of solubles.

(1) San Lorenzo and Pancho Rico Creeks

The contamination in the ground waters in the easterly portion of the San Lorenzo and Pancho Rico deltas may be accounted for by the high concentrations of solubles in the sources of replenishment. Sulphate is the predominating acid radicle in the waters of both San Lorenzo and Pencho Rico Creek. Results of six analyses of samples taken from San Lorenzo Creek over a period of 40 years follow:

	Milligram Equivalents per Liter					
Constituent	8/11/01	4/7/08	8/25/08	5/9/20	6/24/31	12/29/41*
Ca	11.7	8.4	8.0	7.5	12.2	3.3
Mg	9.5	14.9	14.3	16.4	23.4	3.9
Na + K	51.6	27.8	32.7	18.3	42.8	6.1
CO_3	.8	1.2	.8	--	--	--
HCO_3	4.1	4.3	4.7	4.8	5.7	2.7
Cl	21.8	12.2	14.2	12.4	22.0	1.2
SO_4	46.0	37.4	36.0	25.0	51.1	9.4

*Sample taken at flood stage.

All of the foregoing analyses except the one taken at the time of high water on December 29, 1941, show concentrations of sulphate and chloride in excess of amounts considered safe for irrigation use.

The sample taken in 1931 was also tested for boron. It showed 3.08 p.p.m. of elemental boron, which would be toxic for most crop plants.

An analysis of a sample taken from Pancho Rico Creek under the railroad bridge on December 29, 1941, showed the following:

Constituent	M.E./L.	Constituent	M.E./L.
Ca	9.0	HCO_3	2.2
Mg	4.85	Cl	1.65
Na	9.35	SO_4	19.6
Total Cations	23.2	Total Anions	23.45

(2) Inflow from Santa Lucia Range

The surface inflow to the alluvial fill in the Salinas Basin from the Santa Lucia Range, including the Salinas River above the mouth of the Nacimiento River, is generally characterized by low total salinity with bicarbonate being the principal negative ion. The waters contain moderate quantities of sulphates and lesser amounts of chlorides. The averages of analyses of the above mentioned series of samples taken from the principal tributaries between December 1907 and December 1908 are set forth in the following tabulation:

	Milligram Equivalents per Liter			
Constituent	Salinas River at Paso Robles	Nacimiento River near San Miguel	San Antonio River near Bradley	Arroyo Seco near Soledad
Ca	3.00	2.10	3.15	2.55
Mg	2.30	1.80	1.72	1.15
Na + K	3.56	1.04	1.65	1.26
CO_3	.19	.06	.08	--
HCO_3	4.46	2.81	3.67	2.79
Cl	1.10	.40	.68	.37
SO_4	2.02	1.50	1.86	1.50
Number of Samples	30	34	37	34

The good quality of the mixture of the waters of the Salinas, Nacimiento and San Antonio Rivers is indicated by the results of analysis for the Division of Water Resources of two samples taken at San Ardo in 1941, one on August 28 at about the time of the lowest flow for the year, and the other on December 29 during the time of the first winter flood. The results of the two analyses follow:

	M.E./L.			M.E./L.	
Constituent	Aug. 28	Dec. 29	Constituent	Aug. 28	Dec. 29
Ca	2.55	1.25	CO_3 + HCO_3	3.00	1.55
Mg	2.06	.91	Cl	1.30	.35
Na	2.22	.61	SO_4	2.40	.96

The per cent sodium was 33 on August 28 and 23 on December 29, 1941. Total anions were 6.70 on August 28 and 2.86 on December 29.

(3) Salinas River Through Valley Floor

Salinas River is usually influent throughout the year between Metz and Soledad, and between Spreckels and Monterey Bay. The quality of water in these sections during the dry weather season is largely influenced by the ground water inflow. The results of analyses of three samples taken from the river at the Soledad Bridge during low to moderate flows are compared with the quality at flood stage in the following tabulation:

	Milligram Equivalents per Liter				
	5/23/30	5/26/36	8/28/41	Average	12/29/41
Constituent	6 c.f.s.	75 c.f.s.	23 c.f.s.	Low Flow	Flood
Ca	4.94	5.20	5.90	5.35	1.50
Mg	3.03	3.05	3.86	3.31	1.07
Na	1.76	2.26	3.02	2.35	1.56
HCO_3	3.40	4.23	4.45	4.03	2.05
Cl	2.10	2.18	3.00	2.43	.50
SO_4	4.23	4.19	5.47	4.63	1.54

The range in per cent sodium in the three above analyses under low flow conditions was 18 to 24, whereas that under flood flow conditions was about 38. The boron content in the 1930 and 1936 samples was respectively 0.32 and 0.19 p.p.m. All four analyses indicate good quality of water for irrigation purposes.

During midsummer in 1944 and 1945, there was a gradual accretion to the flow of Salinas River from about two cubic feet per second at Spreckels to about 16 cubic feet per second at Mulligan Hill. The quality of water in the river below Spreckels during the low flow season is indicated in the following tabulation:

	Milligrem Equivelents per Liter			
	Spreckels	Blanco	Ft. Ord Road	Mulligan Hill
Constituents	8/28/41	8/16/44	7/26/44	7/26/44
Ca	4.60	5.5	2.7	1.7
Mg	4.95	8.2	3.3	8.2
Na	4.85	4.8	29.2	55.1
CO_3	--	.7	1.2	1.1
HCO_3	7.60	10.1	8.4	7.1
Cl	3.05	5.1	18.8	48.5
SO_4	3.55	2.6	6.8	8.3
Boron (p.p.m.)	--	--	0.60 p.p.m.	0.73 p.p.m.

The foregoing tabulation indicates the small dry weather flow at Spreckels may be usable for irrigation, but the total salinity at Blanco approaches the borderline for safe use. The summer flow at and below the Ft. Ord Road crossing is too saline for irrigation use.

(4) Tributaries to Tembladero Slough

Espinosa Slough had a summer flow in 1944 and 1945 that varied between 10 and 15 cubic feet per second. About half of this flow was diverted for irrigation use by means of four pumping plants between Salinas and the Graves Schoolhouse. The remaining flow commingles with the intermittent discharge of Merrit Lake drainage pump at the head of Tembladero Slough. Alisal and Templades Sloughs are also tributary to Tembladero Slough from the southwest. The quality of the dry weather flow in these four tributaries is indicated in the following tabulation:

	Milligram Equivalents per Liter			
	Alisal at Graves	Templades at Nashua	Merrit Lake at Mouth	Espinosa at Mouth
Constituent	7/23/44	5/10/40	7/23/44	7/23/44
Ca	1.7	2.5	0.7	1.5
Mg	2.5	1.1	1.2	1.6
Na	18.9	6.4	8.1	7.9
CO_3	.0	1.3	.0	.0
HCO_3	13.0	2.1	5.2	6.3
Cl	7.5	5.0	4.0	4.4
SO_4	2.6	1.6	.8	.3
Per cent Na	82%	64%	81%	72%
Boron (p.p.m.)	0.46 p.p.m.	--	0.29 p.p.m.	0.10 p.p.m.

The total salinity in the waters of Alisal Slough was at about the upper limit for safe irrigation use, but was moderate in the other three sloughs. The per cent sodium generally was at or beyond the limit for safety in irrigation use at the time of collection of samples. Tests for boron in the three 1944 samples indicate it was not present in toxic amounts.

Upper Valley Area Ground Water

Reconnaissance of quality of water in the Upper Valley Area with a resistometer indicated no material changes in quality of ground water on the west side of the Salinas River and close to the river on the east side since the former investigation by the Division of Water Resources in 1931-32. The resistivity of samples in this portion of the valley, including wells Nos. 8-H-69 and No. 9-I-2 on which prior complete analyses were made, indicated total solubles ranging from about 650 to 700 p.p.m. The former analyses on the two above wells and the average of three municipal wells in King City in 1940 give an indication of the solubles in the better class of water in the Upper Valley Area. The results of the analyses follow:

	Milligram Equivalents in Liter		
Constituent	Well #8-H-26	Well #9-I-2	Average 3 wells King City
Ca	4.9	3.4	4.6
Mg	.5	3.0	2.6
Na	2.4	3.2	3.9
HCO_3	4.5	4.4	4.6
Cl	1.8	1.5	2.1
SO_4	5.0	3.7	4.4
Per cent Na	30%	33%	35%
Boron (p.p.m.)	.29 p.p.m.	.32 p.p.m.	Not Determined

The ground water contours in the fall of 1944 indicate the foregoing wells are within the influence of percolation from the Salinas River.

(1) Influence of Pancho Rico Creek

Contamination of ground waters in the delta of Pancho Rico Creek east of the influence of percolation from the Salinas River is shown in the analyses of samples taken in October, 1945,

from four wells east of San Ardo. There is a striking resemblance of the quality of water in these wells to the flow in Pancho Rico Creek as shown in the following tabulation:

	Milligram Equivalents per Liter				
Constituent	#12-K-1[illegible]	#12-K-15d	#12-L-16i	#12-K-1	Pancho Rico
Ca	11.6	9.9	11.1	10.7	4.0
Mg	8.4	8.4	6.8	10.	4.9
Na	10.0	8.6	8.5	16.7	9.4
CO_3	.0	.0	.5	.7	.7
HCO_3	4.6	5.2	5.1	3.7	3.2
Cl	4.4	4.4	4.1	3.8	1.7
SO_4	21.0	15.7	16.7	32.2	19.6
Per cent Na	33%	32%	32%	42%	40%
Boron	.73 p.p.m.	.60 p.p.m.	.65 p.p.m.	1.01 p.p.m.	--

All waters in the foregoing tabulation are definitely of sulphate type with too high total salinity for safe use on most crop plants. Boron content is also near the upper limit for sensitive plants.

(2) Influence of San Lorenzo Creek

The influence of percolation from San Lorenzo Creek is indicated by complete analyses of samples from two wells in the southerly portion of the delta Nos. 10-I-8 and 10-I-9 and a well in the northerly portion No. 9-H-2. These three wells are near the easterly edge of the Salinas River influence and the ground water there probably receives replenishment from both sources as compared with wells Nos. 9-I-23 and 9-I-24 in the easterly portion of the delta where dilution from river percolation is not possible. Results of the five analyses follow:

	Milligram Equivalents per Liter				
Constituent	#10-I-8	#10-I-9	#9-H-2	#9-I-23	#9-I-24
Ca	5.6	4.0	9.0	6.5	8.3
Mg	8.2	6.6	10.9	14.6	18.3
Na	3.8	8.9	13.5	19.6	25.0
HCO_3	4.3	3.9	6.9	6.3	7.7
Cl	10.4	10.0	7.5	10.1	12.0
SO_4	4.2	5.7	17.6	33.5	34.8
Per cent Na	20%	46%	40%	48%	48%
Boron (p.p.m.)	1.87 p.p.m.	1.98 p.p.m.	1.30 p.p.m.	4.5 p.p.m.	4.5 p.p.m.

Chlorides, sulphates and boron are all present in toxic amounts in the wells in the easterly portion of the delta. Boron and either sulphates or chlorides are near the upper limit for safe use in irrigation in the wells within the fringe of commingelement of ground water recharge from San Lorenzo Creek and the Salinas River.

Arroyo Seco Cone and Forebay Area Ground Water

The resistometer reconnaissance of well waters in the Arroyo Seco Cone indicated low total solubles ranging from 200 to 300 p.p.m. in the area definitely within the influence of

percolation from the Arroyo Seco. The rapid movement of ground water from the cone into the Forebay Area (hereinbefore estimated to be 31,000 acre-feet per annum between 1929 and 1945) and the high quality of the recharge have apparently prevented any accumulation of solubles in the underground water supply. Results of analyses of samples from two wells within the fringe of comminglement of Arroyo Seco and Salinas River follow:

	Milligram Equivalents per Liter		
	#7-G-22		#7-G-19
Constituent	April 26, 1944	June 10, 1944	June 10, 1944
Ca	1.5	1.5	2.5
Mg	Trace	1.2	2.5
Na	3.6	3.0	3.2
HCO_3	3.2	3.1	4.1
Cl	.9	.8	1.0
SO_4	1.0	1.8	3.1
Per cent Na	70%	53%	39%
Boron (p.p.m.)	.11 p.p.m.	.04 p.p.m.	.05 p.p.m.

The change in per cent sodium in the water of well No. 7-G-22 within a 6-week period as the direction of ground water flow changed within the fringe of comminglement may be noted in the foregoing tabulation.

The amount of water pumped for irrigation use in the Forebay Area during the 1944 irrigation season has previously been estimated as about 77,000 acre-feet as compared with a summer consumption of 35,000 acre-feet. The precipitation during the summer of 1944 on the irrigated land in the Forebay Area supplied about 2,000 acre-feet of consumptive uses. The unconsumed irrigation water of about 44,000 acre-feet largely returned to the pumping zone. This represents nearly half of the previously estimated ground water movement from the Forebay Area to the Pressure Area. A large part of the replenishment in the Forebay Area is made up of ground water flow from the Upper Valley and Arroyo Seco Cone. The Forebay Area thus ultimately receives unconsumed irrigation water applied to all irrigated lands in the valley south of Gonzales. The ground water movement from the area is limited by the bottleneck at the head of the adjacent Pressure Area. The quality of water throughout the Forebay Area is quite spotted, ranging from excellent to fair.

The hills adjacent to the Forebay Area on the east side between Soledad and Coburn Station have a deep soil mantle of a sandy porous texture. There may be appreciable lateral percolation containing high concentrations of solubles from these slopes to the Forebay Area following very wet years such as 1940 to 1942, inclusive. Local residents claim depreciation has occurred in the quality of ground water along the easterly fringe of the alluvium in this area since 1941, but no prior analyses are available to substantiate this contention.

Samples of water from five wells in the older irrigated tracts in the Forebay Area, showing highest total solubles as determined by resistometer test, were analyzed. Samples from four wells in the area showing lowest total solubles were also analyzed. The reports of analysis showing highest total solubles classed these waters as of fair quality for irrigation use as compared with good to excellent quality in the waters of low solubles. A summary setting forth the averages of the analyses follows:

	Milligram Equivalents per Liter	
	Average of #7-F-9, #7-F-13, #7-G-19 and #7-G-32	Average of #5-F-19, #7-G-48, #7-G-49, #7-G-51 and #7-G-55
Constituent	Good Quality	Fair Quality
Ca	1.5	5.3
Mg	1.9	3.1
Na + K	3.7	8.9
CO_3	---	.4
HCO_3	3.1	4.4
Cl	2.	4.1
SO_4	1.8	9.4
Per cent Na	52%	48%
Boron (p.p.m.)	.06 p.p.m.	.21 p.p.m.
pH	7.5	7.7

The variation in total solubles in the ground water in the Forebay Area is indicated by the following resistometer tests:

Well Number	Date	Total Solubles Approximate p.p.m.	Well Number	Date	Total Solubles Approximate p.p.m.
5-F-19	9/ 5/45	1100	6-G-1	1/28/46	640
5-F-20	9/ 5/45	710	6-F-2	1/28/46	750
6-F-3	1/28/46	760	6-F-12	9/ 5/45	710
6-F-27d	1/28/46	620	6-F-22	9/ 5/45	590
6-F-47	9/ 5/45	300	6-F-26	1/28/46	740
6-F-51	9/ 5/45	310	7-F-1	9/28/45	660
7-F-8	9/28/45	800	7-F-9	9/29/45	900
7-F-14	9/28/45	600	7-F-15	9/28/45	720
7-F-20	9/28/45	350	7-G-4	8/23/45	620
7-G-7d	8/23/45	450	7-G-48	8/23/45	1200
7-G-51	8/23/45	1250	7-G-55	8/23/45	1250
7-G-67	8/23/45	375	7-G-10	8/23/45	270

The type of ground water solubles apparently accumulating in various portions of the Forebay Area is compared with that from perched water in the 180-foot aquifer in the vicinity of Salinas under the following discussion of the Pressure Area.

Pressure Area Ground Water

There are two commercial zones of pumping from confined waters in the Pressure Area, hereinbefore designated the 400-foot and 180-foot aquifers. There is also a section of free ground water included in the Pressure Area in the vicinity of the deltas of Quail Creek and Chualar Canyon. This free ground water area appears to be presently replenished by escape from the adjacent confined waters in the Pressure Area. The delta of Moro Cojo Slough in the Moss Landing area, which is partially supplied by exportation from the Castroville area has also been included in the Pressure Area. There appears to be a more or less effective ground water barrier between the confined waters in the Pressure Area and the ground waters in the Moro Cojo delta.

(1) Moss Landing Area Ground Water

Well No. 1- B-21, which was abandoned in 1945, formerly supplied domestic water to the residents in Moss Landing. Analysis of a sample collected from this well on August 8, 1944, showed the following:

Constituent	M.E./L.	Constituent	M.E./L.
Ca	3.2	HCO_3	3.4
Mg	3.3	Cl	5.6
Na + K	3.2	SO_4	.7
Total Cations	9.7	Total Anions	9.7
Per cent sodium		33	
pH		7.53	
Conductance (K x 10^5)		103	

An analysis of a sample of Well No. 1-B-21 on June 10, 1942, showed total solids of 693 p.p.m. and chlorides of 212 p.p.m. or 6.0 M.E./L. This has been a well of low draft with a pressure system capacity of about 100 gallons per minute. The industrial well No. 1-B-20, which was operated at a rate of 400 g.p.m. showed appreciable deterioration in quality of water during approximately the same period of time. Results of analyses of samples from Well No. 1-B-20 follow:

	Milligram Equivalents per Liter	
Constituents	April 29, 1942	August 7, 1944
Ca	2.2	4.0
Mg	2.8	4.9
Na + K	7.5	8.1
HCO_3	3.1	3.1
Cl	9.8	12.4
SO_4		
Per cent Na	60%	48%
pH	7.3	7.6
Conductance (K x 10^5)	---	171

The absence of increment in HCO_3 and an increase in the Cl - HCO_3 ratio between 1942 and 1944 of about 26 per cent are evidence of marine intrusion. This well was abandoned in 1945. Two test wells drilled in 1942 in the Moro Cojo delta to depths respectively of 974 and 1206 feet failed to discover water of quality adequate for industrial uses.

Analyses of samples of water collected in September 1944 from wells numbered 1-B-23 and 1-B-24 indicate the fringe of contamination in the Moss Landing area was at that time between the two wells. Results of these analyses compared with the average of 35 analyses of normal good water in the Blanco-Nashua area are set forth in the following tabulation:

	Milligram Equivalents per Liter		
Constituent	#1-B-24	#1-B-23	Average Blanco-Nashua
Ca	1.5	2.5	1.4
Mg	3.3	3.3	1.8
Na	3.3	.4	2.7
CO_3 + HCO_3	4.2	4.3	3.5
Cl	3.6	1.6	1.7
SO_4	.3	.3	.7
Per cent Na	41%	6.5	45%
pH	7.8	7.8	8.0
Conductance (K x 10^5)	83.2	57.2	62.0

Again the absence of increment in carbonates in the water of well No. 1-B-24 as compared with the nearby well No. 1-B-23 and the large increase in the chloride-bicarbonate ratio may be noted from the above tabulation. Although the conductance and total anions are nearly equal in the water of well No. 1-B-23 and the average good water in the 180-foot aquifer in the Blanco-Nashua area, the constituents in the waters of well No. 1-B-23 are generally outside the range of the 75 other samples of good water.

There are three operating deep wells in the Moss Landing area with first perforations more than 600 feet below ground surface. The temperature of the water in these wells is about 78° F. These wells are designated by numbers 1-B-26, 1-B-29 and 1-B-22i. Analyses of samples collected respectively in June and September, 1944 from the latter two wells follow:

	Milligram Equivalents per Liter	
Constituent	#1-B-29	#1-B-22i
Ca	1.0	0.7
Mg	3.3	.9
Na	9.2	6.2
CO_3	---	.3
HCO_3	3.4	4.1
Cl	8.0	2.0
SO_4	2.1	1.4
Per cent Na	68%	79%
pH	7.8	8.4
Conductance (K x 10^5)	134	82.7

Although the total salinity is moderate in the above waters, per cent sodium is near the upper limit for safe irrigation use. Well No. 1-B-22i is a flowing artesian well when No. 1-B-26 is not in operation. The water level at well No. 1-B-29 generally was about 11 feet higher in 1944-45, than in the nearby No. 1-B-29A, which is about 200 feet in depth. The yields of these deep wells in the Moss Landing area are generally low, being in the order of 400 gallons per minute.

(2) 400 - Foot Aquifer

No evidence was found of any contamination of the water in the 400-foot aquifer with resistometer tests. Total solubles appeared quite uniform between about 275 and 325 p.p.m. Results of analyses of three wells perforated exclusively in the 400-foot aquifer follow:

	Milligram Equivalents per Liter		
Constituent	#2-D-37	#3-D-45	#2-D-39
Ca	0.7	2.6	2.2
Mg	3.3	1.1	1.5
Na	---	.8	.9
HCO_3	2.5	2.6	2.6
Cl	.5	.6	1.0
SO_4	1.0	1.3	1.0
Per cent Na	.0	18%	34%
pH	7.9	8.0	8.1
(K x 10^5)	40.1	---	---

The excellent quality of the above waters for general uses is indicated by the low total solubles, per cent soidum and chloride content. The only other waters in the Salinas Basin known to be of comparable quality are the surface inflow to, and the ground water within, the Arroyo Seco Cone. The average of the above analyses of water in the 400-foot aquifer is compared with the surface flow in the Arroyo Seco on May 1, 1930 with a discharge of 43 cubic feet per second in the following tabulation:

REACTING VALUES - M.E./L.

	Ca	Mg	Na	HCO_3	Cl	SO_4	Total Anions
400-foot Aquifer	1.8	2.0	.6	2.6	.7	1.1	4.4
Arroyo Seco	2.6	1.1	.3	2.8	.3	1.0	4.1

CHARACTER FORMULA - Per Cent

400-foot Aquifer	20.5	22.7	6.8	29.6	7.9	12.5	---
Arroyo Seco	32.5	13.8	3.7	34.1	3.7	12.2	---

GROUPS - Per Cent

	Alkalies	Alkaline Earths	Weak Acids	Strong Acids
400-foot Aquifer	6.8	43.2	29.6	20.4
Arroyo Seco	3.7	46.3	34.1	15.9

CHEMICAL PROPERTIES - Per Cent

	Primary Salinity	Secondary Salinity	Primary Alkalinity	Secondary Alkalinity	Per Cent Sodium
400-foot Aquifer	13.6	27.2	Zero	59.2	14
Arroyo Seco	7.4	24.4	Zero	68.2	8

It may be that prior to commencement of general irrigation in the Forebay Area, the quality of ground water in the Forebay Area was comparable to that now in the Arroyo Seco Cone. If the accumulation of solubles in the ground water in the Forebay Area is of recent occurrence, there may not have been a sufficient lapse of time for the change in quality to show in the 400-foot aquifer in the vicinity of Salinas. Further resort to extractions from the 400-foot aquifer will tend to increase the rate of movement of water therein. There was no draft on the 400-foot aquifer prior to about 10 years ago, and present draft is comparatively light.

(3) 180 - Foot Aquifer

Several early analyses extending back to 1932 as compared with recent analyses indicate no appreciable change in the quality of water in the 180-foot aquifer between a line about two miles inland from the shore of Monterey Bay and a line across the main axis of the valley immediately south of Blanco. The water in this section, with the exception of an occasional well with a leaky casing, shows a remarkable degree of uniformity in total solubles and constituents therein, and the average quality has been designated "normal good water" in the 180-foot aquifer. Samples of water collected in 1944 and 1945 from the 180-foot aquifer south of Blanco showed total solubles ranging from about 500 to 1900 p.p.m. Water in wells in the 180-foot aquifer near the bay shore showed total solubles ranging for about 500 to more than 6,000 p.p.m.

(a) Normal Good Water

Analyses were made of samples collected from six control wells Nos. 1-C-1, 1-C-2, 1-C-11, 2-C-37, 2-C-59 and 2-C-61 in October 1932 in the Blanco-Nashua area during the prior investigation by the Division of Water Resources. Samples were collected and analyzed from the same control wells in 1944, after a lapse of about 12 years. The results of these comparative analyses follow:

Constituent	Milligram Equivalents per Liter											
	#1-C-1		#1-C-2		#1-C-11		#2-C-37		#2-C-61		#2-C-59	
	1932	1944	1932	1944	1932	1944	1932	1944	1932	1944	1932	1944
Ca	2.9	2.2	2.4	2.2	2.7	1.5	3.1	2.3	2.7	2.3	2.5	2.2
Mg	1.7	4.1	1.6	.9	2.0	2.1	2.3	1.8	1.6	2.1	1.4	1.2
Na	2.4	.4	2.3	3.3	2.4	1.8	2.3	2.0	2.2	2.3	1.2	2.1
CO_3 + HCO_3	3.3	3.6	3.6	3.7	3.5	3.2	3.5	3.7	3.1	3.4	3.6	3.0
Cl	1.4	1.4	1.7	1.7	1.5	1.4	1.8	1.4	1.0	1.1	.5	.8
SO_4	2.2	1.7	.8	1.0	1.7	.8	2.0	1.4	2.3	2.2	1.7	1.8
Per cent Na	34	6	34	52	34	33	30	33	34	34	24	36
Boron (p.p.m.)	.21	--	.16	--	.20	.16	.21	--	.18	--	.11	--
K x 10^5	69.4	64.9	63.7	65.3	69.4	70.4	74.0	63.0	63.7	63.1	48.2	60.6
pH	7.6	8.3	7.3	8.0	7.4	7.6	7.5	8.1	7.6	8.0	7.5	8.3

Comparison of the average quality of water in the above six wells in 1932 and in 1944 is made in the following tabulation:

REACTING VALUES - M.E./L.

	Ca	Mg	Na	CO_3+HCO_3	Cl	SO_4	Total Anions
6 Control Wells - 1932	2.7	1.8	2.1	3.3	1.3	1.8	6.4
6 Control Wells - 1944	2.2	2.0	2.0	3.4	1.3	1.5	6.2

CHARACTER FORMULA - Per Cent

6 Control Wells - 1932	20.4	13.7	15.9	25.8	10.2	14.0	---
6 Control Wells - 1944	17.8	16.1	16.1	27.4	10.5	12.1	---

GROUPS - Per Cent

	Alkalies	Alkaline Earth	Weak Acids	Strong Acids
6 Control Wells - 1932	15.9	34.1	25.8	24.2
6 Control Wells - 1944	16.1	33.9	27.4	22.6

CHEMICAL PROPERTIES - Per Cent

	Primary Salinity	Secondary Salinity	Primary Alkalinity	Secondary Alkalinity	Per Cent Sodium
6 Control Wells - 1932	31.8	16.6	Zero	51.6	34
6 Control Wells - 1944	32.2	13.0	Zero	54.8	31

The foregoing tabulations show substantially no change in quality of water in the six control wells over the 12-year period. There are indications of minor base exchanges, but this may be partially absorbed within the accuracy limitation of the analyses. The average of samples of water collected between July 22 and August 23, 1944, from 35 wells perforated in the 180-foot aquifer in quadrants 1-B, 1-C, and 2-C in the Blanco-Nashua district with total anions ranging between 5.1 and 6.6 M.E./L. is taken herein as normal good water in that aquifer. The average of the 35 analyses follows:

Normal Good Water in 180-Foot Aquifer

Constituent	M.E./L.	Constituent	M.E./L.
Ca	1.4	CO_3	0.1
Mg	1.8	HCO_3	3.4
Na	2.7	Cl	1.7
		SO_4	.7
		Total Anions	5.9

Normal Good Water in 180-Foot Aquifer (Continued)

Per cent Sodium -	45
Per cent Chloride -	29
Chloride-bicarbonate Ratio -	0.50
pH -	8.0
Conductance (K x 10^5) -	62.0

The maximum of chlorides in the 35 samples of normal good water in the Blanco-Nashua area was less than 2.0 M.E./L. The carbonate-bicarbonate concentration had the lowest range with variations between 3.0 and 4.1 M.E./L. The range in conductance (K x 10^5) was between 52.0 and 70.4, and approximate mineralization, as determined by the resistometer test, varied from about 350 to 450 p.p.m.

(b) Salinity South of Blanco

All samples of water collected from wells in the 180-foot aquifer south of Blanco as tested with a resistometer showed extra solubles as compared with the above normal good water. The results of 26 of the higher concentrations follow:

Number	Date	Approximate Total Solubles - p.p.m.	Chlorides - p.p.m. by Titration
2-C-78	7/ 6/45	1200	250
2-C-79	5/25/45	1200	230
2-C-80	5/23/45	1400	260
2-C-81	7/27/45	1350	280
2-C-83	7/19/45	1500	340
2-C-84	7/ 2/45	1800	380
2-C-85	6/15/45	1900	460
3-C-54	9/28/44	1600	320
2-D-21	6/ 5/45	1500	240
2-D-32	5/25/45	1300	250
2-D-49	7/ 1/45	1300	270
3-D-4	6/ 5/45	1300	190
3-D-5	5/25/45	1750	320
3-D-10	6/ 5/45	1450	220
3-D-16	5/29/45	1700	300
3-D-17	6/ 5/45	1500	230
3-D-17A	6/ 5/45	1500	230
3-D-19	5/22/45	1400	240
3-D-25	5/24/45	1750	280
3-D-35	5/10/45	1300	240
3-D-42	6/20/45	1500	---
3-D-43	6/ 5/45	1900	350
3-D-80	5/ 7/45	1200	---
3-D-144d	10/20/44	1300	---
4-E-38	9/28/45	1500	---
5-E-71	9/ 5/45	1000	190

Results of complete analyses of samples from five of the above wells and from 5-E-59 follow:

Well Number	Ca	Mg	Na	CO_3	HCO_3	Cl	SO_4
	Constituents - Milligram Equivalents per Liter						
3-C-54	8.2	7.4	7.9	---	7.7	9.0	6.8
2-D-32	6.2	3.7	12.2	0.8	5.0	7.1	9.2
3-D-5	5.0	7.0	14.5	---	8.3	9.0	9.2
3-D-16	13.5	9.0	5.0	---	7.0	8.3	11.2
3-D-25	10.0	7.0	10.8	---	8.7	7.9	11.2
5-E-59	4.9	3.3	12.1	---	9.2	2.9	7.3
Average	7.7	6.7	10.4	.1	7.6	7.4	9.2

Well Number	Conductance K x 10^5	Per Cent Sodium	Hydrogen Ion Concentration - pH
3-D-54	227	54	7.3
3-D-32	189	55	8.1
3-D-5	250	55	7.8
3-D-16	245	59	7.7
3-D-25	248	59	7.8
3-E-59	164	64	7.4
Average	221	43	7.7

The average constituents in the solutions in the above waters of poor quality in the 180-foot aquifer south of Blanco are compared with those in the normal good water in that aquifer and with those previously set forth in water from five wells of fair quality in the Forebay Area in the following tabulation:

REACTING VALUES - M.E./L.

	Ca	Mg	Na	CO_3	HCO_3	Cl	SO_4
Forebay (5) Fair	6.3	3.1	8.9	0.4	4.4	4.1	9.4
Pressure (6) Poor	7.7	6.2	10.4	.1	7.6	7.4	9.7
Normal (35) Good	1.4	1.8	2.7	.1	3.4	1.7	.7

CHARACTER FORMULA - Per Cent

Forebay (5) Fair	17.2	8.5	24.3	1.1	12.0	11.2	25.7
Pressure (6) Poor	15.8	12.8	21.4	.2	15.6	15.2	19.0
Normal (35) Good	11.9	15.2	22.9	.9	28.8	14.4	5.9

GROUPS - Per Cent

	Alkalies	Alkaline Earths	Weak Acids	Strong Acids
Forebay (5) Fair	24.3	25.7	13.1	36.9
Pressure (6) Poor	21.4	28.6	15.8	34.2
Normal (35) Good	22.9	27.1	29.7	20.3

CHEMICAL PROPERTIES - Per Cent

	Primary Salinity	Secondary Salinity	Primary Alkalinity	Secondary Alkalinity	Per Cent Sodium
Forebay (5) Fair	48.6	25.2	Zero	26.2	48
Pressure (6) Poor	42.8	25.6	Zero	31.6	43
Normal (35) Good	40.6	Zero	5.2	54.2	45

The foregoing indicates the same general type of contaminant in both the 180-foot aquifer south of Blanco and the Forebay Area. The chemical properties of the contaminated water as compared with the normal good water show a heavy pick-up in secondary salinity in the form of $CaSO_4$ with an accompanying disappearance of primary alkalinity. There is also a marked increase in carbonate-bicarbonate concentration. A moderate increase occurred in the chloride-bicarbonate ratio from 0.50 in normal good water to 0.93 in the water of fair quality in the Forebay Area and 0.97 in the higher concentrations in the Pressure Area south of Blanco. The salinity encroachment in the 180-foot aquifer near the bay shore is characterized, as hereafter set forth, by an absence of increment in concentration of bicarbonate, i.e., total bound carbon-dioxide, and a much larger increase in chloride-bicarbonate ratio for comparable concentrations of total solubles.

A complete analysis of a water sample from well No. 4-E-38 in October 1932 showed the following:

Per Cent Sodium	Conductance K x 10^5	Boron p.p.m.	Constituents - M.E./L. Ca	Mg	Na	HCO_3	Cl	SO_4
24	47.2	0.13	2.2	1.6	1.2	2.6	0.5	1.7

The foregoing analysis shows no contamination at this well in 1932. A resistometer test of water from this well on September 28, 1945 indicated high concentration of solubles in the order of 1500 p.p.m.

(c) Salinity Near Bay Shore

The water in the 180-foot aquifer near the shore of Monterey Bay, north of the Blanco-Nashua district normal good water, has been classified into four groups in accordance with the degree of concentration of solubles as follows:

Group 1 - Slightly Contaminated

This water is from wells within the fringe of contamination and which are immediately north of the adjacent normal good water in the Blanco-Nashua district. Total anions range from 6.8 to 12.8 M.E./L. This water is classed as good quality and safe for irrigation use.

Group 2 - Moderately Contaminated

This water is from wells between Group 1 and the bay shore. Total anions range from 13.6 to 15.7 M.E./L. This water is classed as fair quality and is considered usable with caution for irrigation.

Group 3 - Injurious Contamination

This water is from wells between Group 2 and the bay shore. Total anions range from 20.6 to 32.3 M.E./L. These waters are usable for irrigation only after dilution with water of better quality.

Group 4 - Highly Contaminated

This water is from wells near the bay shore. Total anions range from 38.6 to 93.9 M.E./L. One well is in use for fire protection and the others have been abandoned.

Fourteen analyses of samples in Group 1 are available as follows:

Well Number	Constituents - Milligram Equivalents per Liter							
	Ca	Mg	Na	CO_3	HCO_3	Cl	SO_4	Total Anions
1-B-7	4.0	2.5	3.0	---	3.3	5.5	0.7	9.5
(1-B-8	2.4	2.1	2.7	---	3.5	3.3	.3	7.1
(1-B-8	2.5	3.3	3.5	---	3.4	5.2	.7	9.3
1-B-10	4.0	1.2	4.7	---	3.5	5.7	.7	9.9
1-B-15	1.5	2.1	3.8	0.2	3.5	2.7	1.0	7.4
1-B-34	1.2	1.6	4.0	---	3.8	2.3	.7	6.8
1-B-39	2.5	2.9	1.6	---	3.6	2.7	.7	7.0
1-B-40	1.5	1.6	6.6	---	3.3	6.1	.3	9.7
1-B-43	4.1	3.1	2.8	---	3.8	5.2	1.0	10.0
1-B-44	5.8	4.1	2.9	---	3.6	7.8	1.4	12.8
1-C-6	1.0	1.2	5.2	---	3.4	2.2	1.8	7.4
1-C-7	1.0	3.3	3.8	---	3.9	2.5	1.7	8.1
1-C-10	2.5	---	8.2	---	3.7	4.3	2.7	10.7
1-C-26	2.2	1.6	3.9	---	3.5	2.5	1.7	7.7
Average	2.6	2.2	4.0	---	3.56	4.14	1.1	8.8

Four analyses of samples in Group 2 are available as follows:

Well Number	Constituents - Milligram Equivalents per Liter							
	Ca	Mg	Na	CO_3	HCO_3	Cl	SO_4	Total Anions
1-B-10	4.0	4.1	7.6	0.3	3.4	11.0	1.0	15.7
1-B-11	4.0	2.9	7.2	.3	3.1	9.9	.8	14.1
1-B-35	4.0	3.3	6.3	---	3.9	9.0	.7	13.6
1-C-10	4.0	3.3	6.3	---	3.3	8.5	1.8	13.6
Average	4.0	3.4	6.8	.1	3.4	9.6	1.1	14.2

Eight analyses of samples in Group 3 are available as follows:

Well Number	Constituents - Milligram Equivalents per Liter							
	Ca	Mg	Na	CO_3	HCO_3	Cl	SO_4	Total Anions
1-B-14	12.5	3.7	12.7	0.7	2.8	23.5	1.9	28.9
1-B-29A	2.2	7.4	11.0	---	3.3	15.8	1.5	20.6
1-B-30	10.0	10.3	12.0	---	2.5	27.9	1.9	32.3
1-B-37	14.5	11.1	5.6	---	3.6	25.9	1.7	31.2
1-B-45	13.8	9.9	7.2	---	3.3	22.6	5.0	30.9
1-B-53	6.2	5.8	10.5	---	3.3	17.3	1.9	22.5
1-B-70p)	10.0	6.7	7.0	T	3.8	17.4	2.4	23.6
1-B-70p)	12.0	8.1	8.0	---	3.7	22.5	3.0	29.2
Average	10.2	7.9	9.3	.1	3.3	21.6	2.4	27.4

Five analyses of samples in Group 4 are available as follows:

Well Number	Constituents - Milligram Equivalents per Liter							
	Ca	Mg	Na	CO_3	HCO_3	Cl	SO_4	Total Anions
1-B-9	11.2	20.6	9.2	---	3.6	35.5	1.9	41.0
1-B-46	21.7	16.4	21.9	---	3.4	53.0	3.6	60.0
1-B-69p	22.3	16.7	24.8	---	3.5	54.2	6.1	63.8
1-B-71p	18.4	12.7	7.5	---	3.2	26.9	8.5	38.6
1-C-48A	39.9	18.5	35.5	---	2.7	87.0	4.2	93.9
Average	22.7	17.0	19.8	---	3.3	51.3	4.9	59.5

The differences between the constituents in the average solubles in the waters of each of the preceding four groups and those in the adjoining normal good water in the 180-foot aquifer are compared in the following tabulation:

REACTING VALUES - M.E./L.

Group	Constituent Increase over Normal Good Water - M.E./L.							
	Ca	Mg	Na	CO_3	HCO_3	Cl	SO_4	Total Anions
1	1.2	0.4	1.3	-0.1	0.16	2.44	0.4	2.9
2	2.6	1.6	4.1	.0	.0	7.9	.4	8.3
3	8.8	6.1	6.6	.0	-.1	19.9	1.7	21.5
4	21.3	15.2	17.1	- .1	-.1	49.6	4.2	53.6
Average	8.5	5.8	7.3	- .1	.0	20.0	1.7	21.6

CHARACTER FORMULA - Constituent Increase in Per Cent

Group	Ca	Mg	Na	CO_3	HCO_3	Cl	SO_4
1	20.6	6.9	22.5	-1.7	2.8	42.0	6.9
2	15.7	9.6	24.7	.0	.0	47.6	2.4
3	20.4	14.2	15.4	.0	-.2	46.2	3.0
4	19.8	14.2	16.0	- .1	-.1	46.3	3.9
Average	19.7	13.4	16.9	- .2	.0	46.3	3.9

GROUPS - Increase in Per Cent

Group	Alkalies	Alkaline Earths	Weak Acids	Strong Acids
1	22.5	27.5	1.1	48.9
2	24.7	25.3	.0	50.0
3	15.4	34.6	- .2	50.2
4	16.0	34.0	- .2	50.2
Average	16.9	33.1	- .2	50.2

CHEMICAL PROPERTIES - Increase in Per Cent

Group	Primary Salinity	Secondary Salinity	Primary Alkalinity	Secondary Alkalinity	Per Cent Sodium
1	45.0	52.8	Zero	2.2	45
2	49.4	50.6	Zero	Zero	49
3	30.8	69.2	Zero	Zero	31
4	32.0	68.0	Zero	Zero	32
Average	33.8	66.2	Zero	Zero	34

The foregoing tabulation shows a striking resemblance in character of the increment in solubles near the bay shore over and above the constituents in the adjacent normal good water. The increase in solubles irrespective of concentration shows absence of carbonate-bicarbonate and practically no alkalinity. It is known that well No. 1-B-35 has a leaky casing and the slight pick-up there in bicarbonate is probably from self-contamination with perched water. It is believed that the other instances of small increase in bicarbonate are due to slight contamination from perched water in addition to the principal contaminant.

The relation between the chloride-bicarbonate ratio and various concentrations of solubles in the contaminated waters near the bay shore and in the adjacent normal good water is indicated in the following tabulation:

Number of Analyses	Average Concentration - M.E./L.			$Cl-HCO_3$ Ratio
	Total Anions	Cl	HCO_3	
35	5.9	1.7	3.4	0.50 to 1
7	7.4	2.6	3.6	.72 to 1
7	10.3	5.7	3.5	1.53 to 1
4	14.2	9.6	3.4	2.82 to 1
8	27.4	21.6	3.3	6.53 to 1
5	59.5	51.3	3.3	15.52 to 1

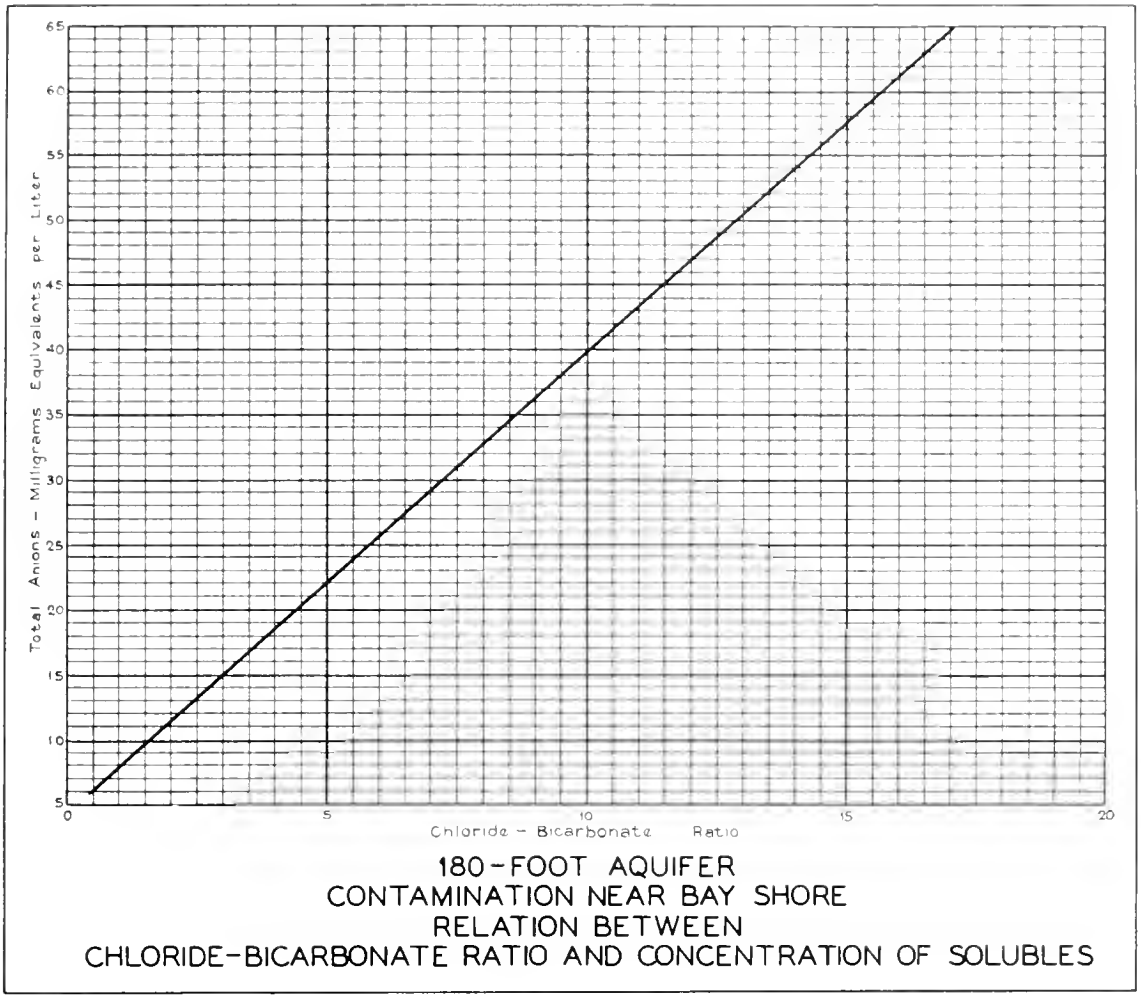
A straight line relationship is indicated on Plate 15 between the above chloride-bicarbonate ratio and concentration of total anions expressed in milligram equivalents per liter. The chloride-bicarbonate ratio of less than 1.0 to 1 in contaminated waters in the 180-foot aquifer south of Blanco and in the Forebay Area for respective anion concentrations of 18.3 and 24.3 M.E./L. indicate the difference in types of contamination in those areas as compared with that in the contaminated water near the bay shore.

Bicarbonate is the most abundant negative ion in the normal good water in the Blanco-Nashua district. This is also generally true of normal ground waters in other areas, whereas the carbonate-bicarbonate constituent in sea water is almost negligible in amount. The weight ratio of chloride to bicarbonate in sea water is about 190 to 1. There is no sewage or industrial waste in the vicinity of the bay shore which could contribute to the contamination north of the normal good water in the Blanco-Nashua district.

(d) Sources of Contamination

It is inferred from the foregoing discussion that the principal source of contamination in the 180-foot aquifer south of Blanco is return to the pumping zone of unconsumed irrigation water which first forms semi-perched water above the upper stratum of blue clay. A small amount of sewage and industrial waste also contributes to the perched water. Perched water levels in 1944-45 ranged from about 3 to 10 feet below ground surface, whereas the pressure surface of the 180-foot aquifer ranged from about 15 to 45 feet below ground surface. Opportunity for drainage of perched water into the pumping zone is afforded through many unplugged wells with collapsed

PLATE 15



180-FOOT AQUIFER
CONTAMINATION NEAR BAY SHORE
RELATION BETWEEN
CHLORIDE-BICARBONATE RATIO AND CONCENTRATION OF SOLUBLES

casings in the Salinas-Spreckels districts. There may also be natural openings through the blue clay and some drainage may occur over the fringe of the impervious stratum. Ground water flow from the Forebay Area, containing a lesser concentration of the same type of contamination has probably also accentuated the condition. There has not been a sufficient lapse of time for ground water movement to carry the contamination as far north as Blanco.

The foregoing discussion, coupled with a downward slope of the pressure surface from the bay shore to the inland during a substantial portion of the irrigation season and absence of sewage and industrial wastes, leads to an inference that the contamination near the bay shore is a result of sea water encroachment. The analyses of the admixture indicate this may be either recent or fossil sea water. The existence of a deep ocean canyon a short distance off-shore, where the pressure surface apparently maintains an elevation of near mean sea level, strongly suggests direct marine intrusion as the principal source of contamination.

(e) Quality at Different Depths

A portable electrode and resistometer were used to test the quality of water at different depths in four wells in the 180-foot aquifer near the bay shore. One of the wells had been idle for about five months during the winter of 1944-45. The second well had been abandoned for about 18 months due to excessive salinity. Two of the wells were new wells that had never

been operated.

Well No. 1-B-35 which had been idle for about five months showed a gradual increase in solubles from about 1500 p.p.m. at depth 20 feet to about 1700 p.p.m. at depth 274 feet. (bottom of well).

Well No. 1-C-53n, which had been abandoned for about 18 months showed the following differences in quality at various depths:

Depth Below Ground Surface	Resistance Ohms	Temperature Degrees F.	Approximate Solubles p.p.m.
20'	50	65	2200
40'	50	65	2200
60'	50	65	2200
80'	50	65	2200
100'	45	65	2350
120'	40	65	2700
140'	30	65	3500
160'	18	65	5200
174'	15	65	6000

The foregoing tabulation indicates the tendency of the salinity to settle to the bottom of tha well after a comparatively long period of idleness. A further illustration of this tendency is that of the Bellone domestic well No. 1-B-72d, which has had a windmill installation ever since it was drilled to the 180-foot aquifer in 1928. Abandoned wells of high salinity ranging from 3,000 to more than 6,000 p.p.m. surround this domestic well. (Wells Nos. 1-B-69p, 1-B-70p, 1-B-71p, 1-B-46, 1-C-49n, 1-C-49A and 1-C-53n). Well No. 1-B-72d, which has a low maximum draft of about five gallons per minute, shows normal good water from the windmill discharge. This indicates salinity encroachment is along the bottom of the aquifer and the low draft is inadequate to cause salt to surge and mix in the top water in the aquifer.

Wall No. 1-B-61, which had been recently drilled, showed a slight increase in salinity from about 1080 p.p.m. at depth 20 feet to about 1150 p.p.m. near the bottom of the well at depth 151 feet. Recently drilled well No. 1-B-60 showed no change in solubles of about 700 p.p.m. betwaen top and bottom water. Intermittent samples collected during the process of development of wall No. 1-B-60 showed the following changes in quality:

Development commenced at 9:45 A.M. on April 25, 1945.

Time	Approximate Solubles - p.p.m.
April 25 - 10:00 A.M.	640
10:15 A.M.	520
11:00 A.M.	450
1:00 P.M.	430
2:00 P.M.	420
5:00 P.M.	420
Pump stopped at 5:00 P.M. on April 25. Pumping resumed at 5:30 A.M. on April 26.	
April 26 - 8:00 A.M.	420
Tritration of a sample at 8:00 A.M. on April 26 showed chlorides - 57 p.p.m.	
July 24 - 5:00 P.M. (after 10 hrs. operation)	500

(f) Rate of Movement of Contamination

The fringe of contamination near the bay shore was defined in August, 1944. At that time wells immediately outside the fringe and within the adjacent zone of normal good water included the following: 1-C-19, 1-C-12, 1-C-11, 1-B-13, 1-B-52, 1-B-62d, 1-B-42, 1-B-63n, 1-B-41,

1-B-17, 1-B-31, 1-B-33i and 1-B-23. The position of the fringe was checked again in August, 1945. During the one year period, the position of the fringe moved inland not more than one-eighth mile at any place. There was no appreciable movement of the fringe toward wells Nos. 1-C-12 and 1-C-19, probably due to the influence of ground water inflow from the Neponset Sand Ridge. The ridge in the pressure surface in the vicinity of Neponset serves to deflect the inland movement of ground water from the bay shore in an easterly direction during the irrigation season. The low salinity in the ground water flow from the Neponset Sand Ridge is indicated by the analysis of a sample collected on July 26, 1944 from well No. 1-C-55d, which is situated near Neponset immediately southwest of the blue clay zone. The results of analysis of the sample from well No. 1-C-55d follows:

			Constituents - M.E./L.						
K x 10^5	Boron p.p.m.	pH	Ca	Mg	Na	CO_3	Cl	SO_4	Total Anions
44.7	0.03	7.55	0.5	0.6	1.5	0.5	1.5	0.6	2.6

The rate of movement of the fringe of contamination closely checks the velocity of ground water flow on the bay side of the trough in the pressure surface previously set forth in Chapter VI.

CHAPTER VIII

EVALUATION OF PRESENT WATER PROBLEMS

The foregoing analyses of basic data indicate the water problems in the Salinas Basin are of two general types. One type includes the difficulties induced by development and utilization of the ground water supply, and the other embraces problems inherent from natural conditions. Primary sources of trouble induced by water utilization are overdrafts. When overdraft occurs, secondary problems arise which are evil manifestations incidental thereto. Although the induced and inherent problems are interwoven, insofar as is possible, separate evaluation of each is hereafter set forth.

Overdraft in 180-Foot Aquifer

The rate of safe yield of the 180-foot aquifer in the Pressure Area has been calculated to be approximately 230 cubic feet per second. The combined rate of draft from this aquifer in 1945 exceeded the rate of safe yield for a period of more than six months during the irrigation season. The rate of excess draft varied from about 15 to 100 cubic feet per second between April 8 and October 13. The overdraft caused a steeper hydraulic gradient in the pressure surface to obtain than that prevailing for safe yield rate, which in turn increased the rate of movement of water therein from about 10 to 45 cubic feet per second above the rate of safe yield. The overdraft was made up by movement of water toward the inland from Monterey Bay at rates during the period in 1945 varying from zero to about 55 cubic feet per second.

The cumulative amount of the excess in rate of total draft over and above the rate of safe yield of the 180-foot aquifer in 1945 was approximately 20,000 acre-feet. This represents the approximate amount of water that must be substituted for present draft on the aquifer in order to eliminate actual overdraft. This amount of water should be available for substitution over a 6-month period at rates up to a maximum of about 100 cubic feet per second to prevent marine intrusion.

The apparent overdraft, i.e., the cumulative amount of the excess in rate of total draft over and above the rate of downstream flow in the 180-foot aquifer in 1945 was approximately 12,000 acre-feet. If the hydraulic gradient that prevailed during the irrigation season in 1945 from the fountain head down to the trough in the pressure surface can be maintained through substitution in place of pumping, then the amount of water that must be substituted for present draft on the aquifer to eliminate present overdraft would approximate 12,000 acre-feet per annum. This amount under such conditions should be available for substitution over a 6-month period at rates up to a maximum of about 55 cubic feet per second to prevent marine intrusion.

(1) Marine Intrusion

Marine intrusion has occurred in the 180-foot aquifer in recent years as a result of overdraft. There was no evidence of such contamination in October 1945 at any well more than 1-3/4 miles from the bay shore. The average distance of the fringe of contamination from the bay shore at that time was about 1½ miles. The total length of the contaminated strip, including the Moro Cojo sub-basin in the Moss Landing area, was about 6½ miles. The gross area embraced within the zone of contamination was approximately 6,000 acres, about 25 per cent of which was in

the Moss Landing area. The wells within about half of the contaminated zone contain water that are presently either unusable for irrigation, or are near the upper limit in salinity for safe use.

The inland rate of encroachment of the fringe of contamination was slow between August 1944 and August 1945. The average movement during this period of the year was about 600 feet. Although the rate of encroachment was slow during that time, the concentration of the salinity rapidly increased in wells of heavy draft within the zone of contamination. The chloride constituent more than doubled in the water solubles in many of the wells during the year. Pumps of low draft for domestic purposes may skim off water of good quality from the top of the aquifer where there are no nearby wells of heavy draft to surge the salinity to the upper waters.

There was no appreciable flushing action of fresh water replacing saline waters during the winter season in 1944-45 in the 180-foot aquifer near the bay shore. The drainage from the aquifer to the bay during the winter season may largely be in the form of good water with lower specific gravity flowing above the more sluggish saline water. Moderate industrial draft throughout the winter in this area may distort the contours of the pressure surface and contribute to lack of flushing. It has been the experience in Santa Clara Valley Water Conservation District that a lapse of several years, with draft less than safe yield, is required to restore a well after the waters therein had become too saline for safe irrigation use.

The maximum distance that marine intrusion may encroach in the 180-foot aquifer is the most inland position of the trough in the pressure surface under conditions of heaviest draft. If water supply and draft conditions in 1945 were maintained indefinitely, salinity encroachment might approach but not extend beyond the trough position hereinbefore shown on Plate 13. (The small difference in head due to difference in specific gravity of water on the bay and inland sides of the trough would have negligible effect on the distance of encroachment). There was an area of about 9,200 acres irrigated in 1945 between the bay shore and the trough position shown on Plate 13.

(2) Contamination from Perched Water

Many of the early drillings to the 180-foot aquifer between Spreckels and the bay shore resulted in flowing artesian wells. These wells were flowing in this area at least as late as 1916-17. After lettuce and double-crop truck became important in the Pressure Area subsequent to 1924, the elevation of the pressure surface lowered substantially during heavy summer draft, and there was an accompanying rise in perched water levels. Prior to that time, if there was opportunity for circulation between the perched water and water in the 180-foot aquifer, there was escape from the aquifer to the perched water zone due to the difference in head then prevailing. The head differential is now reversed and perched water levels are generally higher than the pressure surface elevation in a major portion of the area throughout the year.

There is little evidence of any contamination in the pumping zone from perched water between Blanco and the bay shore. Several isolated wells showing appreciable self-contamination have either been repaired or properly plugged in recent years. This has largely been done after investigation by, and under the direction of, Mr. Sydney A. Tibbetts, industrial chemist and geologist, in 1931, 1937 and 1938. The owners and tenants south of Blanco have not been alerted to the possibility of severe damage to, if not destruction of, the most precious natural resource of the area by contamination of the pumping zones with perched water.

Several wells in the 180-foot aquifer between Spreckels and Blanco have been abandoned in recent years due to excessive salinity from perched water infiltration, and deeper wells perforated exclusively in the 400-foot aquifer have been substituted therefor. There may be natural breaks or openings in the blue clay stratum between the perched water and the 180-foot aquifer, which would permit circulation of the two waters, but abandoned wells in this area with collapsed casings that have never been plugged, even if not the exclusive contributors, have doubtless accentuated the contamination.

Most of the wells in the 180-foot aquifer within and immediately adjacent to the strip embraced between the Davis Road and Monterey Road shown on Plate 17 show salinity approaching the upper limit for safe irrigation use. A major portion of the wells in the 180-foot aquifer between Salinas and Gonzales show varying amounts of contamination from a trace to near the upper limit of safe irrigation use. There was no information gathered during the investigation indicating a tendency to stabilization with the exception of well No. 3-D-82 analyzed in 1938 and 1944. Further investigation over a period of years is necessary to determine if contamination from perched water is generally progressive in this area. If the condition is cumulative, possibilities for damage are extensive if corrective measures can not be devised and carried out.

Overdraft in East Side Area

The measured total surface inflow to the East Side Area during the seasonal runoff year October 1, 1944 to September 30, 1945 was 2700 acre-feet. The estimated surface inflow during the preceding year 1943-44 was 1800 acre-feet. The entire surface inflow was retained in the area during the 2-year period. The average annual retention of surface inflow within the East Side Area has been estimated to be 5,000 acre-feet.

The total consumption of water within the East Side Area was about 52,000 acre-feet in 1943-44 and 53,000 acre-feet in 1944-45. Direct precipitation on the area respectively supplied about 38,000 and 39,000 acre-feet in 1943-44 and 1944-45. Consumption of ground water within the East Side Area approximated 14,000 acre-feet during each of the two seasonal runoff years. Excluding consideration of the net difference in ground water inflow and outflow (which is believed to be small), consumption of ground water within the East Side Area during the 2-year period exceeded replenishment approximately 23,000 acre-feet. Under normal conditions of consumption and replenishment and with demand based on cultural classifications prevailing during the 2-year period, the overdraft would be in the order of 7,000 acre-feet per annum. The normal consumption of ground water in the adjoining area of 5,000 acres overlying free ground water in the Pressure is about 3,000 acre-feet per annum.

Irrigation Efficiency

Comparatively low irrigation efficiencies under prevailing practices for certain crops grown in Salinas Valley contribute materially to the water problems. This applies in general to lettuce and celery irrigation in the Pressure Area and to lettuce, truck, beans and sugar beets in the free ground water areas south of Gonzales. The relation between the summer consumption of water on irrigated land and amount of water applied, while not a true measure of irrigation efficiency, may be used to indicate the relative irrigation efficiencies. The irrigation efficiency

will be somewhat less than the ratio of summer consumption to irrigation water applied on a tract, due to carry-over of winter precipitation in the soil and summer rains available to partially supply summer consumption of water.

(1) Pressure Area

Nearly 40 per cent of the irrigated land in the Pressure Area was devoted to double-crop lettuce or lettuce double-cropped with celery in 1944 and 1945. The average summer consumption was approximately 30 per cent of the irrigation water applied. The summer consumption on the remaining 60 per cent of irrigated land in the Pressure Area was about 66 per cent of the irrigation water applied.

Less than 10 per cent of the irrigation water pumped in the Pressure Area returned to the pumping zone in 1944 and 1945. A large part of the irrigation water not consumed on the irrigated land was dissipated as outflow to the bay, transpiration by native vegetation and other uneconomic consumption. Low irrigation efficiency in the Pressure Area thus directly contributes to the rate of overdraft in the 180-foot aquifer. Elimination of extractions in excess of beneficial requirement would give direct relief to overdraft on the aquifer.

(2) Areas South of Gonzales

Approximately 75 per cent of the irrigated land south of Gonzales was devoted to the production of beans, sugar beets, truck and lettuce in 1944 and 1945. The average summer consumption on these crops was approximately 33 per cent of the irrigation water applied. The summer consumption on the remaining 25 per cent of irrigated land south of Gonzales was about 80 per cent of the irrigation water applied.

Substantially all of the unconsumed irrigation water south of Gonzales returns to the pumping zone. Low irrigation efficiencies on about 75 per cent of the irrigated land indicates unnecessary leaching of the topsoil. This directly contributes to increase in concentration of mineral solubles in the ground water in this area which tends to accumulate in the Forebay Area. Some leaching action is necessary to keep the root zone soil in a healthy condition, but the amount actually required is only a fraction of the indicated unconsumed irrigation water in a major portion of the area.

Increase in irrigation efficiency and a decrease in leaching action to minimum requirements would result in a tendency to stabilization of mineral solubles in the ground water at lesser concentrations. Continued low irrigation efficiency in these areas of free ground water over a period of years will tend to accentuate the toxicity of contamination from perched water in the Pressure Area.

Inherent Problems

Water problems existing by virtue of natural conditions include contaminants in the sources of ground water replenishment originating on the Diablo Range, high pumping lifts on the bench land, heavy drawdowns in certain wells, and limited capacity for percolation from the Salinas River.

(1) Natural Contaminants

Ground waters receiving replenishment from sources naturally contaminated with toxic

amounts of solubles are limited in extent. The affected area embraces only the easterly portions of the deltas on Pancho Rico Creek and San Lorenzo Creek. Fortunately this is a condition that is not apt to spread because these streams usually flow only intermittently during the mid-winter season at times when large quantities of good water from other sources are available for dilution.

(2) High Lifts on Bench Land

Static water levels are less than 60 feet below ground surface in more than half of the valley fill in the Salinas Basin. There are limited areas of bench land in the Arroyo Seco Cone and Upper Valley Area where depth to water exceeds 180 feet. These lifts exist because of the elevation and location of the bench land in respect to the natural sources of replenishment. The pumping lifts in the Arroyo Seco Cone and Upper Valley Area will probably not change much over a period of years, even with anticipated increase in water utilization. The ground water in these areas annually recharge to the maximum extent possible except in critically dry years.

Depth to static water level on about 6400 acres in the East Side Area exceeded 180-feet in the fall of 1944. Progressive lowering of water elevations may be anticipated in the East Side Area due to existing overdraft. In those sections of the area where ground water inflow from the Pressure Area is possible to offset overdraft, water levels there should stabilize at elevations somewhat lower than those prevailing in the adjacent Pressure Area. Wells in lenses sealed from contact with aquifers in the Pressure Area may ultimately become dry holes.

(3) Drawdowns in Operating Wells

The specific capacity of wells in the Salinas Basin is generally high. Yields in excess of 100 gallons per minute per foot of drawdown are quite common. Occasional wells have specific capacities of less than 10 gallons per minute per foot of drawdown. Wells of low yield are generally obtained in the overlap fringes of deltas in the East Side Area where large proportions of the alluvium are fine materials.

The deeper sands and gravels in the 400-foot aquifer, while not as thoroughly explored as the 180-foot aquifer, appear to have more compaction and cementation than the upper water-bearing formations. The new well No. 1-B-73 with a 14-inch casing in the 400-foot aquifer on the Bellone Ranch has a drawdown of about 80 feet for a yield of 800 gallons per minute. Well No. 3-D-48 with a 16-inch casing in the 400-foot aquifer has a drawdown of 35 feet with a yield of 800 gallons per minute. The lower specific capacities on some wells may be partially due to improper well development, which may be subject to correction.

(4) Limited Capacity for Percolation from Salinas River

The limited capacity for percolation from the Salinas River in the Forebay and Pressure Areas appears to be the principal natural condition contributing to water problems in the Salinas Basin. Due to an impervious stratum between the river bed and the pumping zone through the Pressure Area, there is little, if any, replenishment of water in the aquifers from river percolation between Gonzales and Monterey Bay.

The underground storage capacity in the Forebay Area has either been full, or nearly full, during the past 16 years. The average capacity for additional percolation from the Salinas River during the irrigation season has been in the order of 10,000 acre-feet. Any development

work that would serve to maintain water levels throughout the year at river bed levels in the Forebay Area would be ineffective relief for overdraft conditions in the 180-foot aquifer and in the East Side Area. Such water levels maintained in the Forebay Area would cause an average theoretical increase in the movement of water through the 180-foot aquifer of only about two per cent. Maintenance of complete recharge of ground water in the Forebay Area could not affect overdraft in the East Side Area.

CHAPTER IX

ULTIMATE DEMAND FOR WATER

Increased future demand for water in the Salinas Basin will depend primarily on change of cultural classification on lands in the group designated in Table 4 of Appendix A as irrigable to irrigated crops. During the 6-year period following 1939, there was a total change of approximately 17,000 acres of dry-farm and grass land culture to irrigated crops. There remained in the Salinas Basin at the end of the 1945 irrigation season slightly more than 50,000 acres of irrigable land not heretofore irrigated.

Approximately 41 per cent of the irrigated land in the Salinas Basin in 1944 and 1945 was double-cropped. Lands devoted to perennials such as artichokes, orchard, guayule and alfalfa are not subject to double-cropping. Approximately 25 per cent of the total irrigated acreage is presently devoted to such perennials. The long growing season required for sugar beets does not permit double-cropping other than a green manure crop. The proportion of about one-eighth of the total irrigated acreage devoted to sugar beets is not apt to change much because of its suitability as a rotation crop for lettuce and truck about one year out of three. Beans as grown in the blue clay zone in the Pressure Area are a single crop on land that is being rested for return to double-cropping. Such rested lettuce land in beans represented about five per cent of the total irrigated acreage in 1944 and 1945.

The only opportunity for much expansion in double-cropping appears to be in the bean land overlying free ground water. Double-cropping as practiced with beans is limited to winter crops that mature in early spring such as winter lettuce and peas. The water requirements of such winter crops are largely supplied by rainfall which would otherwise be consumed through evaporation and transpiration by winter grasses growing on the land. The normal annual consumption on double-crop bean land varies from about five to 10 per cent more than for single crop beans.

Guayule culture in the Salinas Basin reached a peak of 8,783 acres in 1944. This crop is not generally grown on land suitable for lettuce and vegetable truck. It is anticipated that the guayule acreage will rapidly shrink back to the pre-war area of about 5,000 acres with a corresponding increase in beans. The annual consumption of water on bean land is substantially the same as on the land devoted to guayule in this area.

Basis Used in Estimates

The estimates of future increases in demand for water in the Salinas Basin are based on the assumption that all of the 50,000 acres of irrigable land will ultimately be brought under irrigation. There was no increase in irrigated acreage during the recent depression years after 1931 and until 1939. The irrigated acreage in this period held remarkably steady in view of unfavorable crop prices. It fluctuated between a low of about 88,000 acres in 1934 and 105,000 acres in 1937. The rapid increase since 1939 makes it unsafe to assume that anything less than the entire irrigable area will ultimately be placed in irrigated crops.

It is further assumed that the average normal annual consumption of water per acre of irrigated land in each of the free ground water areas will remain constant, i.e., the net change

in types of irrigated crops and irrigation practices will not materially change the average annual water consumption per acre of irrigated land. The increased annual consumption of water in a free ground water area thus may ultimately approximate the difference between the annual unit consumptive use on irrigated and irrigable land multiplied by the irrigable acreage.

It is also assumed that the average amount of water pumped per acre of land in the Pressure Area in 1944 will remain constant and that the entire amount of increased extractions in the blue clay zone will go to evapo-transpiration and outflow to Monterey Bay. The difference in unit water utilization on town and farm lots and average irrigated land is not material.

Upper Valley Area

The irrigable land not heretofore irrigated in the Upper Valley Area embraces about 14,000 acres. The average difference in normal annual unit consumption in this area between irrigated and irrigable land is approximately 1.30 feet in depth. The annual increase in consumption of water in the Upper Valley Area may approach 18,000 acre-feet under ultimate development.

The Salinas River normally flows through the Upper Valley and Forebay Areas on to Monterey Bay between about January 1 and June 15. That portion of the increased consumption occurring between about June 15 and the end of the year would normally be supplied from underground storage. The distribution of water consumption for alfalfa, as hereafter set forth in Table 29 in Appendix A, of about five-eighths of the total annual, which normally occurs between June 15 and the end of the year, is taken as indicative of average for irrigated crops. This indicates the average annual decrement in ground water storage may ultimately approach an additional 11,000 acre-feet in this area. The information hereinbefore set forth in Chapter VI indicates that this would probably cause an additional average seasonal drop in water levels of about two feet in the Upper Valley Area.

Arroyo Seco Cone

The possibility for additional expansion of irrigated land in the Arroyo Seco Cone is limited to about 2,000 acres. The average difference in normal annual unit consumption in this area between irrigated and irrigable land is approximately 1.37 feet in depth. The annual increase in consumption of water on the Arroyo Seco Cone may approach 3,000 acre-feet under ultimate development.

The entire flow in the Arroyo Seco during the irrigation season usually is retained on the cone. Any increase in consumption of water between April 1 and November 1 would largely be at the expense of ground water storage. The average annual ground water outflow from the Arroyo Seco Cone would probably be reduced by an amount comparable to the annual increase in consumption of water on the cone.

Forebay Area

An area of about 4,000 acres of pasture land in native annual grasses may ultimately be brought under irrigation in the Forebay Area. The average difference in normal annual unit consumption in this area between irrigated and irrigable land is approximately 1.42 feet in depth.

The annual increase in consumption of water in the Forebay Area thus may approach 6,000 acre-feet under ultimate development.

The Salinas River normally has surface outflow through the Forebay Area to Monterey Bay from about January 1 to June 15. Based on the assumption that there is complete replenishment of ground waters in this area until the river ceases to flow, and using the consumption distribution for alfalfa as average for irrigated crops, the indicated annual decrease in ground water storage may approach 4,000 acre-feet under ultimate development in the Forebay Area.

Increased consumption of ground water in the Upper Valley Area and Arroyo Seco Cone will tend to reduce the ground water inflow to the Forebay Area. This will create additional capacity in the Forebay Area for percolation from the Salinas River. It is anticipated that the approximate net effect of increased consumption of water in the Salinas Valley south of Gonzales would be a corresponding decrease in surface outflow to Monterey Bay. The average annual decrease in surface outflow past Gonzales may approach 27,000 acre-feet under ultimate irrigation development if the area in native vegetation remains constant. However, under the projected channel improvement plan of the Corps of Engineers, U. S. Army, an area of about 6,000 acres now in native vegetation on bottom land south of Gonzales may be reclaimed and placed in irrigated crops. This would result in a net annual salvage of about 3,000 acre-feet, since average unit consumption by irrigated crops in these areas is about one-half foot in depth less than by native vegetation. This salvage would tend to increase surface outflow by a corresponding amount.

East Side Area

An approximate area of 18,000 acres of dry-farm and grass land in the East Side Area offers the greatest possibility for expansion of irrigated lands in the Salinas Basin. The average ground water replenishment from the tributary watersheds on the Gabilan Range will not support further expansion of irrigated land in this area. The average annual difference in normal unit consumption of water between irrigated and irrigable land in this area is about 0.76 foot in depth under prevailing irrigation practices. The possibility for increased annual consumption of ground water in this area is in the order of 14,000 acre-feet under maximum development. The ultimate annual overdraft, including that estimated to presently exist, may approach 21,000 acre-feet.

Ground water storage in the East Side Area is now in the process of exhaustion as heretofore indicated on Plates 8 and 9. Insofar as the water-bearing formations in this area are not sealed from contact with the aquifers in the Pressure Area, the deficiency may be made up by escape of confined waters in the latter area. Only time can fully demonstrate what portion of the overdraft may be ultimately concentrated in the Pressure Area.

From the standpoint of the economy of the Salinas Basin it would be undesirable for any portion of overdraft in the East Side Area to be borne by the 180-foot aquifer where overdraft also presently exists. A complete solution of water problems in the basin must embrace minimum annual enhancement of water supply in the East Side area to the extent of about 7,000 acre-feet to meet present deficiencies and about 21,000 acre-feet in the ultimate plan.

Pressure Area

Irrigation water pumped in the Pressure Area in 1944 was about 2.07 acre-feet per acre.

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The to[illegible]l [illegible]r[illegible]ft, inclu[illegible]ing municipal [illegible]nd industrial u[illegible]es, in the Pressure Are[illegible] may under the forego[illegible]ing assumptions ultim[illegible]tely [illegible]pproach 14[illegible],000 [illegible]cre-feet during the irrig[illegible]tion [illegible]e[illegible]son between [illegible]pril 1 [illegible]nd November 1. Combined consum[illegible]tion [illegible]nd outflow [illegible]f irrig[illegible]tion w[illegible]ter may [illegible]pproach 12[illegible],000 [illegible]cre-feet [illegible]s com[illegible]re[illegible] with [illegible]bout 10[illegible],000 [illegible]cre-feet in 1945.

Increased consumption of water south of Gonzales will tend to [illegible]ure slightly lower water elevations at the fountain head of the 180-foot aquifer each year after the Salinas River [illegible]ases to flow past Gonzales. The [illegible]ver[illegible]e increase in loss of head at the fountain head between [illegible]bout June 15 and the close of the irrigation season should be small, probably not in excess of two feet. Possibilities of escape of water from the 180-foot aquifer to partially offset overdraft in the East Side Area appear to offer a more serious threat to accentuation of the problem of marine intrusion.

There has been a decided recent trend to favor drillings to the 4[illegible]0-foot aquifer in the Pressure area. It is probable that a substantial portion of irrigation expansion in this [illegible]rea will be supplied from the deeper aquifer. If all the irrigable l[illegible]nd in the blue clay zone w[illegible]s placed under irrig[illegible]tion, the continuous flow equivalent during [illegible] 3-week period of peak demand in midsummer would be increased by about 80 cubic feet per second under prevailing irrigation practices. If present trend continues, probably not more than half of this ultimate increase would be supplied by the 180-foot aquifer.

Any lands reclaimed in the Pressure Are[illegible] for irrigated crops under the proposed channel improvement progr[illegible]m may increase the draft on confined waters. The [illegible]re[illegible] susceptible of reclamation embraces about 5,000 acres, which under existing practices would increase the demand for irrigation water in the order of 10,000 acre-feet per annum. This would incre[illegible]se the continuous flow equivalent of midsummer demand by about 30 cubic feet per second. A substantial portion of this likewise may be supplied by the 400-foot aquifer where some surplus appears to presently exist.

An increased draft on confined waters in the Pressure Area will induce a greater flow of ground water by virtue of a steeper hydraulic gradient th[illegible]t would obtain. Apparent overdraft in the 180-foot aquifer will thus increase [illegible]t [illegible] slower rate than the increase in demand, and actual overdraft will rise directly with the dr[illegible]ft.

A complete solution of the pr[illegible]blems in the Salinas Basin should embrace [illegible] present [illegible]nnual enhancement of the w[illegible]ter supply in the Pressure Area in the order of 20,000 acre-feet. The ultimate enhancement required may approach 55,000 acre-feet per [illegible]nnum less the qu[illegible]ntity that may be extracted from the 400-foot aquifer under safe yield [illegible]onditions. The [illegible]dditional amount that may [illegible]e extracted from the 400-foot aquifer is uncertain [illegible]nd is not susceptible of reli[illegible]ble definition, in the absence of expensive exploration work, until further devel[illegible]pment has [illegible]ccurred. It is unsafe to assume that the 400-foot [illegible]quifer offers much toward the solution of the problem [illegible]ther than temporary relief.

CHAPTER X

METHODS OF CONSERVATION

The first step in the matter of water conservation is ascertainment of areas where additional water is required. The next involves determination of amounts of supplemental water necessary to meet requirements. The third is discovery of surplus or unused waters adequate in quantity and quality to supply the demands. The final step is investigation of methods of salvage of such unused waters to make them available for beneficial uses.

It has been revealed in the foregoing analyses that overdrafts presently exist in the East Side and Pressure Areas. The amount of firm water required to relieve present shortages in these areas has been determined to be in the order of 27,000 acre-feet per annum. The ultimate annual deficiency in these areas may approach 76,000 acre-feet less such additional water as may safely be extracted from the 400-foot aquifer under voluntary resort thereto. Demand under ultimate development offers no threat to overdraft on ground waters in the Salinas Basin south of Gonzales. Relief of overdrafts would not necessarily entail any material increment in ground water outflow.

The magnitude of the average annual waste from the Salinas River stream system to Monterey Bay, compared with present and estimated ultimate requirements for additional water to meet the demand, presents an encouraging outlook for solution of problems of overdraft in the East Side and Pressure Areas. A salvage in the order of five per cent of the average total outflow would eliminate present overdrafts. Ultimate demand may necessitate salvage in the order of 15 per cent of the average total outflow. Inclusion of cyclic storage in the amount of 160,000 acre-feet over a 10-year period would require present and ultimate salvage respectively of about eight and 18 per cent of the average total outflow. These estimates of salvage required are to be taken as approximations subject to more accurate determination during the period of ultimate development in some such manner as hereafter described.

An average annual flow of approximately 444,000 acre-feet, or about five-sixths of the average total outflow from the Salinas Basin flows from the Forebay Area in the form of surface waste. It has hereinbefore been estimated that about one-third of the remaining one-sixth has occurred as ground water outflow from the Pressure Area largely during the winter season when irrigation demand was light. The remaining estimated average annual outflow has the following sources:

Tributaries to alluvium north of Arroyo Seco	36,000 acre-feet
Precipitation on alluvium	10,000 acre-feet
Irrigation return and sewage	13,000 acre-feet

Surface waste from tributaries to the alluvium north of the Arroyo Seco and from precipitation on the valley floor is unreliable. The outflow therefrom is negligible in years that are slightly subnormal in precipitation. The irrigation return and sewage outflow, which occur in the blue clay zone of the Pressure Area, are comparatively steady under prevailing irrigation practices. This latter source may provide some firm water but the ultimate solution must include salvage of a portion of the large surface outflow from the Forebay Area.

Underground storage within the 60-foot zone below ground surface in the order of 100,000 acre-feet, on which draft has never been made, exists in the Forebay Area and Arroyo Seco Cone.

General Available Methods of Salvage

Salvage of irrigation return flow, i.e., a portion of applied irrigation water unconsumed through evapo-transpiration on crop land, can best be accomplished by increasing the irrigation efficiency to eliminate all extractions for non-beneficial uses. Outflow from irrigation return is limited to the blue clay zone in the Pressure Area. Drainage from the blue clay zone is not susceptible of re-use due to a high concentration of solubles that generally prevails. The method of salvage is limited to elimination of unnecessary pumping, which would reduce the occurrence of waste by a corresponding amount. A decrease in draft on the 180-foot aquifer would increase the elevation of the pressure surface near the bay shore and would, within a few days, tend to check marine intrusion.

Two methods of utilization of surface outflow from the Forebay Area are available. A diversion system must be included in each method to accomplish salvage. Surface reservoir sites on the Arroyo Seco, San Antonio River, and Nacimiento River have received much attention in the 1904 report by Homer Hamlin, in the 1933 report by the Division of Water Resources, and in the current flood control survey by the Corps of Engineers, U. S. Army. The other method involves development work designed to induce more percolation to underground reservoirs. Past attention given to this latter method has been restricted to proposed spreading works on the Arroyo Seco Cone as set forth in the 1933 report by the Division of Water Resources. Further consideration will hereafter be given to increased percolation in other areas of free ground water.

Irrespective of the method of salvage employed, a complete solution must embrace a plan of delivery of water impounded either in surface or underground reservoirs to the places where additional water is required. The foregoing analyses show that released surface storage and increased percolation in the alluvium south of Gonzales would, without artificial means of conveyance, be ineffective to relieve overdraft in the East Side Area and on the 180-foot aquifer in the Pressure Area. No site was found for a gravity diversion from the Salinas River between San Ardo and Monterey Bay. Diversion from the lower 93 miles of the Salinas River appears to be limited to a pumping installation. There was almost complete failure of surface outflow from the Salinas Basin during five years of record (1913, 1924, 1931, 1933, and 1939). A pumping installation so located that released surface storage, unused underground storage and surplus natural surface flow could be diverted for conveyance to the places of overdraft, would offer ideal flexibility.

Surface Storage

Prior investigational work by the Division of Water Resources included the collection of more or less detailed information on 26 reservoir sites in the Salinas Basin. Geological reconnaissance was made during the 1931-32 investigation of the more meretorious sites. No favorable reservoir sites appear on the east side tributaries to the Salinas River either because of lack of runoff or poor quality of water.

The Corps of Engineers, U. S. Army, in the current flood control survey on the Salinas River is giving further study to such of the above reservoir sites found worthy of investigation for flood control purposes as well as water conservation. It appears that feasibility of surface storage for water conservation hinges on the suitability of the site for flood control and usability as a dual-purpose project. It is outside the scope of this report to duplicate work heretofore done or in the process of investigation by other governmental agencies.

Prior estimates have been made of costs of surface storage in five reservoir sites with substantial flood control possibilities. These were the El Nacimiento and Peblestone Shut In on the Nacimiento River, Pleyto "B" on the San Antonio River, Foster on the Arroyo Seco, and Wunpost on the Salinas River. Various capacities, water supplies, and estimated unit costs per acre-foot of storage, based on 1940 construction costs, are summarized in the following tabulation:

Site	Water Supply Acre-feet		Capacity Acre-feet	Approximate Cost per Acre-foot Capacity
	Mean	Minimum		
El Nacimiento	207,000	17,000	97,000	$34
Pebblestone Snut In	121,000	10,000	77,000	45
Pleyto "B"	86,000	2,000	58,000	30
Foster	105,000	10,000	61,000	58
Wunpost	475,000	28,000	310,000	41

No water would have been available for storage in any of the above reservoirs in five out of 44 years between 1902 and 1945, inclusive, when the entire flow was naturally retained in the basin. Up-to-date analyses of surface storage are included within the scope of the flood control survey being made by the Corps of Engineers, U. S. Army. A diversion system would be required to make released storage from each of the above reservoirs available for relief to present and ultimate overdrafts in the East Side and Pressure Areas. A cost analysis of a diversion system that would deliver released storage to both areas from any of the above reservoirs, except the Foster Site, which could also effect diversion of unused underground storage is hereafter set forth. The Foster Site, which has the highest estimated cost per acre-foot of storage capacity, is to situated that delivery of storage releases therefrom would entail heavy additional costs.

Salvage of Irrigation Return and Sewage

(1) Sewage Effluent at Salinas

The effluent from the sewage disposal plant of the City of Salinas is the only municipal sewage outflow from the Salinas Basin. The effluent is dumped in the Salinas River immediately north of the Davis Road crossing northwest of Salinas. The quantity of discharge to the river during the summer of 1945 fluctuated between about two and 8 cubic feet per second and was estimated to average about five cubic feet per second. The winter discharge was less. The total salinity is near the borderline of safety for irrigation use. The quality of water in the 180-foot aquifer in the vicinity of the disposal plant is also approaching the upper limit for safe irrigation use. Dilution of the effluent with water pumped from the 400-foot aquifer would probably make it safe for irrigation use. The amount available for use during the irrigation season in 1945 was in the order of 3,000 acre-feet. The initial cost of salvage would principally consist

of drilling a 500-foot well to obtain good quality [illegible] costs for a 500-foot well with a 16-inch casing are about $5,[illegible]. Current pumping costs for drafts of about 2.5 cubic feet per second on the 400-foot aquifer in this area are under $[illegible] per acre-foot. Annual carrying charges on the combined effluent and dilution water are estimated at about $2,500. The combined flow during the irrigation season of about [illegible],000 acre-feet, while small, would have low unit cost.

(2) Industrial Wastes

Packing shed washwater and ice plant cooling water in and near Salinas is mostly discharged into Espinosa Slough. About half of the total average discharge of approximately 12 cubic feet per second in 1945 was pumped from the slough for irrigation use. The source of this water, prior to industrial use, is the 180-foot aquifer in the Salinas area where moderate contamination presently exists. The water in Espinosa Slough is only of fair quality for irrigation. Due to probability of further deterioration in quality and also to liklihood of eventual abandonment of water cooling at all ice plants in the area, salvage of industrial wastes in Espinosa Slough may be properly classed as a temporary supply providing about 1,000 acre-feet during the irrigation season. Cost of salvage for use on abuting lands would be nominal.

The per cent sodium in the small summer flows of Merritt Lake Drain and Alisal Slough is too high for safe irrigation use. The seepage from the percolation ponds of the beet sugar factory at Spreckels, while of fair quality for irrigation use, occurs too late in the season to be of much value for irrigation. Beet nematode infestation in the water makes it unsafe for irrigation use until after filtration.

(3) Irrigation Efficiency

Continuous records kept in 1945 of amount of water pumped from wells Nos. 1-C-27, 2-C-73, and 4-D-10 for lettuce irrigation indicate that two crops of good quality per acre may be successuflly grown, without reduction in profit, with a gross application of 18 to 22 inches in depth. Well No. 1-C-27 is near Neponset, No. 2-C-73 is between Blanco and Salinas, and No. 4-D-10 is in the East Side Area east of Spence. The records of power consumption at several additional wells show a similar gross duty of water for double-crop lettuce under the better irrigation practices in the basin. However, the average practice in the Pressure Area with a gross application of about 32 inches in depth per annum on double-crop lettuce seems to be extravagant use of water compared with the better practice. The use on several tracts is much greater than average.

The total amount of water pumped in the Pressure Area in 1945 has hereinbefore been estimated to be 120,000 acre-feet. Approximately 50,000 acre-feet was disposed of as surface outflow from irrigation return and sewage, consumption by native vegetation, and other uneconomic consumption. The overdraft on the 180-foot aquifer in 1945 was about 40 per cent of the total waste and uneconomic consumption in the Pressure Area.

Irrigation efficiency in the Salinas Basin may be increased by an educational program, which may result in voluntary improvements in irrigation systems and practices. Many suggestions

for betterments consistent with maintenance of quantity and quality of produce without reduction in the margin of profits have been set forth hereafter in Appendix C. Results of such an educational program are uncertain and slow of materialization.

An assured increase in irrigation efficiency in general conformity with prevailing good practices in the basin mey be expeditiously effected through an administrative determination of rights to extract ground water under the court reference procedure set forth in Sections 2000 to 2050, inclusive, of the Water Code (Chapter 368, California Statutes of 1943). The amount of water that might be salvaged in this manner through elimination of pumping for non-beneficial uses is not susceptible of ascertainment in the absence of a detailed adjudication investigation. The magnitude of the applied irrigation water that is unconsumed on the irrigated land in the Pressure Area encourages a belief that salvage possibilities in this area alone may be in the order of the current overdraft on the 180-foot aquifer. If such a quantity of water could be salvaged in this manner, it would be the least expensive type of water conservation.

Salvage Through Increase in Percolation

Increase in precolation may be accomplished in the Salinas Basin either by spreading surplus water over areas of free ground water where empty underground storage capacity exists, or by draft on unused underground storage to create space for additional natural percolation.

(1) Arroyo Seco Cone

The total inflow from the Arroyo Seco to the alluvium during 329 days between October 1, 1944 and September 30, 1945, was retained within the Arroyo Seco Cone. Also the first percolation from surface inflow in the Forebay Area during the seasonal year 1944-45 came from the Arroyo Seco. Approximately 51,000 acre-feet or 48 per cent of the total inflow from the Arroyo Seco was retained within the cone and the first 9,000 acre-feet of outflow from the cone was retained in the Forebay Area. The total natural regulation of the Arroyo Seco through retention in the alluvium of the basin in 1944-45 was about 60,000 acre-feet or 57 per cent of the total inflow from that stream. The period of time in 1944-45 when there was surface outflow to Monterey Bay from the Arroyo Seco commingled with other waters in the Salinas River embraced 35 days. A large portion of the outflow during the 35-day period occurred in a flood, which was unfavorable to spreading because of muddiness of water and hazardous conditions for spreading operations.

The average number of days per annum during the 44-year period 1902 to 1945, when there was surface outflow from the Arroyo Seco Cone has been estimated as 51, the total flow being retained in the cone for an average of 314 days per annum. After deducting the time when the total outflow from the cone was retained in the Forebay Area (on which no information is available) and when the flow is too high for successful spreading operations, the average net discharge and number of days of occurrence available for this type of water conservation are comparatively small.

The effectiveness of spreading surplus flow of the Arroyo Seco as a remedy for current and ultimate water problems in the Salinas Basin is an important consideration. The favorable percolation beds are embraced within an area of about 1600 acres of waste land adjacent to the stream between the head of the old Spreckels Canal and the lower bridge on the Arroyo Seco. There is no water problem on the Arroyo Seco Cone, except high pumping lifts on the bench land. The potential

spreading beds are too low in elevation in respect to the bench land to provide any material relief for this inherent problem. Increased ground water outflow from the cone to the Forebay Area would probably be the principal effect of percolation in the area favorable for spreading works. There is no present or ultimate problem in the Forebay Area with the exception of a tendency toward deterioration in quality of water. Increased ground water inflow to the Forebay Area would probably not be helpful in retarding progressive accumulation of solubles in the ground water. It has been previously explained that maintenance of complete recharge of ground waters in the Forebay Area would provide ineffective relief for problems of overdraft on the 180-foot aquifer and in the East Side Area. It therefore appears that a spreading project on the Arroyo Seco Cone would accomplish little in the way of a solution of current and ultimate water problems in the basin. Increased percolation on the cone, with no supplemental works to recapture the percolate for use in areas with deficient supplies, would probably be offset by a comparable increase in surface outflow and natural disposal of other inflow to the Forebay Area.

(2) Unused Underground Storage

The foregoing analyses indicate existence of underground storage in the Forebay Area and in the lower portion of the Arroyo Seco Cone in the order of 100,000 acre-feet within the 60-foot zone below ground surface on which no draft has ever been made. It has also been shown that approximately 88 per cent of the average total surface outflow from the Salinas Basin passes across this area. Utilization of this unused underground storage would, without further development works create facilities for salvage of a comparable amount of surface waste by increased percolation within the area directly from the channels of the Salinas River and Arroyo Seco.

(a) Favorable Location for Flexibility

The Forebay Area and lower portion of the Arroyo Seco Cone are favorably situated in respect to areas of overdraft in the basin for utilization of unused underground storage to eliminate the deficiencies. The underground reservoir also has a strategic location for flexible operation in conjunction with released surface storage from any important reservoir site in the basin with the exception of those on the Arroyo Seco. Diversion from underground storage should be restricted to places south of the fountain head of the 180-foot aquifer a sufficient distance to prevent drawdown from having any material effect on prevailing water elevations at the northerly fringe of the Forebay Area. Any material drawdown at the fountain head would decrease the presently deficient ground water movement through the Pressure Area. Favorable pumping sites for delivery of supplemental water to a major portion of the East Side Area appear to be situated in the vicinity of where the course of the Salinas River changes from the east toward the west side of the valley about three miles southeast of Soledad. The specific capacity of wells with 16-inch casing in this vicinity ranges from 100 to 300 gallons per minute per foot of drawdown. Water raised to elevation about 265 feet on the bench north of and midway between wells Nos. 7-G-5 and 7-G-6n could be conveyed by gravity to a major portion of the East Side Area and to any point in the Pressure Area. Total pumping lift would approximate 100 feet.

(b) Development Offers Solution

Any method of enhancement of water supply in the East Side and Pressure Areas adequate to eliminate present and prospective overdraft must embody a diversion system. Approximately

80 per cent of the total surface inflow to the East Side Area is retained in the area. The outflow therefrom is not worthy of salvage consideration due to infrequency of occurrence and inadequacy in total amount. If supplemental water is conveyed as far as Alisal Creek from the Forebay Area, no construction difficulties would be encountered in transportation of additional water to drop through to Espinosa Slough for conveyance by natural channel to the contaminated area in the vicinity of Castroville. This source also could be used instead of the 400-foot aquifer as an alternate supply in the vicinity of Salinas where contemination from perched water is serious.

The underground reservoir in the Forebay Area would remain fully replenished during the early part of the irrigation season until the Salinas River ceased to flow past the Gonzales bridge. The system would thus in fact serve to divert direct diversion from the Salinas River from the time of commencement of the irrigation season until outflow from the Forebay Area ceased. Draft on underground storage would then commence and continue until the close of the irrigation season. There would then be opportunity of recharge of the underground reservoir from about 88 per cent of the average total surface outflow from the basin. The underground reservoir would thus be much more certain of filling in dry years than any surface reservoir with a more limited watershed.

The primary purpose of such a diversion system, as above suggested, would be for direct use through existing distribution systems in areas of overdraft in lieu of draft on local supplies. However, use for this purpose would incidentally build up cyclic underground storage in the East Side Area. The average amount of irrigation water applied in the East Side Area in 1944 was about 2.2 acre-feet per acre of irrigated land, whereas the averege normal consumption of irrigation water applied is about half that amount. The unconsumed irrigation water in this area largely returns to the pumping zone. Thus if the entire present draft in the East Side Area were supplied from the Forebay Area, the annual contribution to ground water in the area would be in the order of 16,000 acre-feet. A complete substitution in source of supply for the East Side Area would thus in time fully recharge the empty ground water storage capacity in that area, heretofore established to be in the order of 200,000 acre-feet between the water table in 1945 and 60 feet below ground surface. A comperable additional capacity exists between 12 and 60 feet below ground surface. This supply would be available for emergency use within the area and no difficulty would be encountered in transfer for use to the Pressure area in years of extreme drouth.

An accumulation of cyclic underground storage in the East Side Area would reverse the present direction of ground water movement from the Pressure Area to the former area. Incidentally the East Side Area may eventually assume its former capacity of serving as a lateral forebay area to the Pressure Area and thus cause an increase in present movement of water through the partially confined aquifers during the irrigation season.

Draft of unused underground storage from the Forebay Area would establish more movement of ground water therefrom, a highly desirable condition. It will tend to improve the quality of water therein through greater percolation of surface flows of the Salinas River and the Arroyo Seco.

Adequate unused underground storage is immediately available to meet all present requirements for additional water in areas of overdraft. Continued observations of general effect on ground water as a result of increased draft from the Forebay Area would allow a more accurate evaluation of the amount of surface storage required for ultimate development in the basin. Successive steps in a comprehensive plan to meet ultimate requirements for water conservation call first for salvage of available wastes with lowest unit cost and thence in order of expense for recourse to the methods of greater unit cost. The more expensive water may in this manner be held to a minimum in the final phase of development.

Of course if surface storage for flood control purposes is found to be feasible, or nearly feasible, it would be desirable for water users to participate in the project to reduce pumping costs and to provide maximum cyclic underground storage in the Forebay Area, as an additional factor of safety.

Conservation of Quality of Water

Further protective measures pointed toward conservation and improvement of quality of water supplies in the Salinas Basin deserve equal consideration with those designed to maintain adequacy in quantity. Slow movement of ground water operates against rehabilitation after contamination has occurred. Therefore conservation measures for protection of quality should be preventive rather than corrective.

Many "defective wells" in the older irrigated sections in the basin are either still in operation or have been abandoned without being properly plugged. The term "defective well", as used herein, means any water well drilled, dug or excavated, which encounters unpotable water or water containing substances toxic to crop plants and which is so constructed as to permit the commingling of such contaminated water with waters of better quality, or a flowing well which lacks the necessary devices to control waste of water therefrom.

There are acceptable methods for prevention of construction of defective wells and also for repair of defective wells if they are to be continued in use. The construction of defective wells as above defined should of course be prohibited. Any existing defective wells, which are to be continued in use, should be repaired. If contaminated water lies above the stratum containing better quality of water, the well should be recased either by withdrawing the old casing and replacing it with new casing of like diameter, or by inserting a new casing of smaller diameter inside the old and sealing the annular space between them. If contaminated water lies below the stratum containing better quality of water, such contaminated water should be shut off by plugging that portion of the hole between the bottom of the well and the bottom of the stratum containing the better quality of water.

Whenever a defective well is abandoned it should be plugged. If practicable, the well should be cleaned out prior to plugging and then properly filled with heavy clay laden fluid or concrete.

The top of a well should be adequately equipped to prevent any surface contamination. The outside casing should extend above ground surface a suitable height to prevent entrance of surface water. Pump pits, whenever installed, should be sealed and built up to a comparable height above ground surface.

Construction of return wells for the purpose of recharging ground waters should not be discouraged. Any such plan should be subject to approval and supervision by a competent authority to prevent disposal of contaminated waters in this manner in all cases where filtration through alluvium is inadequate to remove deleterious substances.

There appears to be adequate law set forth in the Water Code of California (Sections 300 to 311, inclusive) to eliminate occurrence of waste from flowing artesian wells. These laws should be enforced.

In order to enable intelligent action under the foregoing protective measures, standards for uniform logging of wells should be adopted. All well logs should be filed with a central governmental agency within a limited period of time after completion.

Provision for enforcement of protective measures may be made either through County ordinance, or State law, such as the 1945 enactment by the State of Ohio, 96th General Assembly, House Bill No. 339, Section 408-3F of the General Code.

As far as is known there are no defective wells in the 400-foot aquifer. It is a matter of prime importance to the welfare of the basin that all possible safeguards be established to protect the good water prevailing in that aquifer. Rehabilitation of the quality of water in the 180-foot aquifer would be a slow process even if all the foregoing measures were taken. There are doubtless many defective wells, long since abandoned, that either cannot be found, or which it would be impractical to clean and effectively plug. However, establishment of protective measures would tend to retard contamination from perched water. Much has voluntarily been done since 1931 in the Nashua district in the way of repairing or plugging defective wells.

Cost Estimate of Diversion System

A reconnaissance survey was made of a diversion system that could be utilized to divert both unused underground storage from the Forebay Area and from flow in the Salinas River south of Soledad. A canal heading on the northeast bank of the Salinas River at about elevation 265 feet was selected for the reconnaissance. Other possible routes may prove, after detailed surveys, to be more feasible. The proposed layout of the diversion has previously been indicated on Plate 1A.

(1) Canal Capacity Required

The estimated canal capacity required to deliver 25,000 acre-feet to the East Side Area and 20,000 acre-feet to the Pressure Area during the irrigation season is about 150 cubic feet per second. This is adequate to eliminate estimated present overdrafts and provide approximately 16,000 acre-feet per annum of cyclic underground storage. Estimated loss through consumption by native vegetation and other uneconomic consumption is 2000 acre-feet per annum. Ultimate canal capacity required may approach 250 cubic feet per second to permit a gross delivery of about 76,000 acre-feet during the irrigation season. It is assumed for purposes of this analysis that the initial development would include construction of a lined canal with a capacity of 250 cubic feet per second. Use of concrete lining from the head of the main canal for a distance of about 23 miles to the South Branch of Alisal Creek is assumed. Consideration should be given in final studies to selection of other types of lining developed in recent years which may give satisfactory results with less expense.

The lined section of the canal would have inside dimensions of 8 feet bottom, 20 feet top and 4 feet depth. The slope would be 0.0005, and "n" in Kutter's Formula assumed to be 0.014, the capacity would approximate 250 cubic feet per second. The lined section would be all in cut.

An extension of the main canal from the South Branch of Alisal Creek would be made, commencing at elevation about 155 feet and extending on a slope of 0.0005 approximately six miles to Natividad Creek. The water section in cut would be 6 feet bottom, 15 feet top and 3 feet depth. With "n" in Kutter's Formula assumed to be 0.020, the capacity would approximate 80 cubic feet per second.

Water for delivery to the Pressure Area would be conveyed down the natural channel of the South Branch of Alisal Creek for a distance of about three miles to the canalized channel leading to and through Heins Lake and Carr Lake and thence into Espinosa Slough. Diversion would be made from Espinosa Slough near the Monterey Branch Railroad Crossing for delivery to the area subject to marine intrusion. A regulating reservoir with a capacity of about 300 acre-feet would be constructed in Heins Lake or some other convenient place enroute to allow flexibility of operation.

(2) Distribution System

The principal distribution system in the East Side Area and in the northerly portion of the delta area would include 40 gravity take-outs through 20-inch buried concrete pipe, each equipped with a take-out gate and two valves to permit connection with 120 existing closed conduit distribution systems. There would also be 20 additional gravity 16-inch take-outs to serve open distribution systems adjacent to the canal. Service in the Salinas-Spreckels section of the Pressure Area would be by gravity closed conduit from the regulating reservoir at Heins Lake. No direct service is included under the initial distribution system on the north side of Gabilan Creek in the East Side Area. Under prevailing direction of ground water movement from Natividad Creek toward Santa Rita, the area north of Gabilan Creek may receive adequate recharge of ground water from the substituted supply and may not require direct supplemental service under ultimate development. About 20 check-gates would be required to effect diversion from the canal.

(3) Diversion Wells and Pumps

The initial diversion wells and pumping plants would be on the bottom land along the northeasterly side of the Salinas River where lowest costs for headworks installation exist. Later installations would be constructed in units of six plants as required.

A sump would be constructed on the bottom land immediately opposite the head of the canal on the bench land to the north. Six pumping installations around the sump would discharge directly into the sump. Half of the remaining 30 wells would be upstream from the sump and the others on the downstream side. There would be 18 plants in a line close to the river about 300 feet apart. Another line of 18 plants would be parallel to the other, staggered end set back about 500 feet. A semi-circular metal flume about one-half mile in length with a capacity of 64 cubic feet per second would be installed on timber supports between the two staggered lines of plants downstream from the sump to transport the discharge from 15 plants up to the sump. A concrete lined canal would convey water from the upstream plants to the sump.

The estimated initial headworks required would embrace 36 diversion wells drilled to an average depth of about 200 feet. Each would be equipped with a deep well turbine type pump with a 60-foot column. Each plant would have a capacity between 1800 and 2000 g.p.m. for a range in total pumping lift between 20 and 45 feet. Estimated average total lift is 35 feet.

There would be six initial booster units installed, each with a capacity of 25 cubic feet per second, to elevate water from the sump to the head of the canal. The total booster lift would be fairly constant at about 65 feet.

(4) Miscellaneous Structures

Miscellaneous structures include flume crossings, each about 60 feet long, over Stonewall and Chualar Canyons and Quail and Alisal Creeks. There would also be crossings over seven minor swales. Farm road crossings at 20 points and 8 county road bridges are included.

Rediversion dams would be required in the two southerly tributaries to Alisal Creek and in Espinosa Slough. The channel sections are about 30 feet in width. A collar-type concrete dam, equipped to insert 5 feet of flashboards, would be used.

(5) Estimated Initial Costs

Estimates hereafter set forth have been based on unit costs as of the end of the year, 1945. Unsettled labor conditions and unstable prices of materials may cause substantial and rapid changes in construction costs during the post-war period. Estimated construction costs of the foregoing tentative diversion system follow:

Main Canal	
Canal - Mile 0 to Mile 12.0 Capacity, 250 second-feet	
Excavation, 177,400 cu. yds. earth at $0.25	$ 44,400
Concrete lining, 1,534,600 sq. ft. at $0.225	345,300
Trim earth for canal, 170,500 sq. yds. at $0.40	68,200
- Mile 12 to Mile 23.0 Capacity 250 - 150 second-feet	
Excavation, 126,600 cu. yds. earth at $0.25	31,600
Concrete lining, 1,283,600 sq. ft. at $0.225	288,800
Trim earth for canal, 142,600 sq. yds. at $0.40	57,000
Structures	
Farm road crossings, 24 at $1100	26,400
County road crossings, 8 at $6000	48,000
Metal flumes - 660 lineal ft. at $50	33,000
Canal checks - 20 at $1250	25,000
Natividad extension canal - Length 6 miles Capacity, 80 second-feet	
Excavation 60,200 cu. yds. at $0.25	15,000
2 rediversion dams at $6000	12,000
Natural channel	
Excavation, 40,000 cu. yds. at $0.20	8,000
Rediversion dam at $10,000	10,000

Distribution system	
16-inch take-outs, 20 at $40	800
20-inch take-outs, 40 at $60	2,400
20-inch valves, 80 at $175	14,000
16-inch plain concrete pipe, 7000 lin. ft. at $0.85	6,000
20-inch reinforced concrete pipe, 120,000 lin. ft. at $1.35	162,000
Regulating reservoir - 300 acre-feet	8,000
Headworks	
200 ft. wells, 36 at $1400	50,400
Deep well turbine pumps and motors 36 at $1700	61,200
Booster pumps and motors, 6 at $5600	33,600
65 second foot capacity metal flume, 2400 lin. ft. at $20.00	48,000
65 second foot lined canal, 2400 lin. ft. at $4.00	9,600
Pump sump	5,000
28-inch discharge pipe, 600 lin. ft. at $6.00	36,000
12-inch discharge pipe, 9000 lin. ft. at $3.00	27,000
Subtotal	$1,444,300
Administration and engineering 10 per cent	144,400
Contingencies at 15 per cent	216,600
Right of ways - 500 acres at $500	250,000
Interest during construction at 3 per cent	61,700
Total cost	$2,117,000

(6) Estimated Annual Carrying Charges

Annual carrying charge on initial costs has been computed with interest at three per cent and amortization in 40 years. Power costs of pumping have been computed on the basis of Schedule P-15, effective in 1945 for electric power service in the Salinas Valley. Annual charges on cleaning natural channel have been based on one complete cleaning per 10-year period. Annual maintenance on pumps, motors and diversion wells has been calculated on the basis of three per cent of initial cost of installation. Depreciation on pumps and motors is based on replacement in 25 years. Allowance for general annual maintenance has been made on the basis of one per cent of the balance of construction costs. Demand for water under the initial installation has been based on substitution of 25,000 acre-feet in the East Side Area and 20,000 acre-feet in the Pressure Area during each irrigation season. Estimated annual carrying charges follow:

Annual Costs -

Capital cost $2,117,000	
Interest 3%	$ 63,500
Amortization 3% 40 yr. s.f. basis .0133	28,200
Electric Power (P.G.&E.Co.) 45,000 A.F. at 2.00	90,000
Caretakers	10,000
Maintenance pumps, motors, wells $187,000 at .03	5,600
Depreciation pumps and motors 25 yrs. at .03 s.f. basis $122,000 at .027	3,300

Annual Costs (Contd.)

Cleaning natural channel	$ 800
General Maintenance	10,000
Increased cost in Forebay Area (75,000 ac. ft. at $0.20)	15,000
Total annual costs	$226,400

The gross cost per acre-foot including interest, amortization, operation and maintenance for 45,000 acre-feet of substituted supply would approximate $5.00 based on prices at the end of year 1945. Average cost for power alone of water from existing supplies is estimated at $2.90 per acre-foot. It is estimated that annual return to the pumping zone of unconsumed irrigation water applied from the substituted supply in the East Side Area and in the Quail Creek section of free ground water in the Pressure Area would approximate 16,000 acre-feet or about 35 per cent of the total diversion. This quantity of water placed in cyclic storage would go to the benefit of all water users, not directly receiving subsitute water, in the East Side and Pressure Areas. No evaluation is made of probable benefits in the Forebay Area to tendency in improvement in quality of ground water as a result of increased outflow.

Cost of Development of 400-Foot Aquifer

An estimate of cost for additional water through further resort to the 400-foot aquifer is hereafter set forth for comparative purposes. The estimate is based on individual development of 500-foot wells with 16-inch casing and an average draft per well during the irrigation season of 500 acre-feet with an average total lift of 80 feet. The annual carrying charges on initial costs are based on interest at 4 per cent and amortization in 40 years. Estimated annual carrying charges follow:

$5,000 well - interest and amortization	$ 243
$1,900 Pump and motor - interest and amortization	96
Annual maintenance (4% of initial cost)	276
Electric Power at $1.80 per acre-foot	900
Total annual charges	$1,525
Cost per acre-foot	$ 3.05

Dual Purpose Surface Storage

In the event that surface storage is developed at some time in the future in the Salinas River stream system south of Soledad for flood control purposes, consideration should be given to benefits that may be received by water users from participation therein for purposes of water conservation.

The initial development as hereinbefore set forth would utilize in average years approximately 17,000 acre-feet of direct diversion from the Salinas River prior to about June 15 and about 28,000 acre-feet of underground storage subsequent to June 15. Surface storage which would be available for release after about June 15 each year to maintain recharge of ground water in the Forebay Area would eliminate the item in carrying charges of increased cost in the Forebay Area hereinbefore estimated at $15,000 per annum. The decrease in annual power costs for diversion is estimated at $9,000 under conditions of flow in the river past the diversion wells throughout the irrigation season. Maintenance of complete replenishment of ground water in the Forebay Area at the close of the irrigation season would provide additional cyclic underground

CHAPTER XI

LEGAL CONSIDERATIONS

The foregoing analyses have been based strictly on engineering principles. Successful consummation of plans embracing a complete solution of water conservation problems in the Salinas Basin involves more than engineering. The existence of several hundred overlying landowners and appropriators in the basin creates legal obstacles to development designed to salvage waste. Enhancement of water supply to eliminate overdrafts requires disposal of legal problems that will be encountered. Legal difficulties may eliminate adoption of certain water conservation plans, which are feasible from the standpoint of engineering.

The development of the ground waters in the Salinas Basin has been typical of that by individual effort in many other areas. It has proceeded without supervision or adequate information of results on the part of those using the water. Such information usually comes after alarm is caused by deterioration in quality of water and receding water levels, or after a series of lawsuits, which may be inconclusive. Problems of overdraft are not necessarily the sole concern of those being damaged by deterioration in quality of ground water, recession in water levels, and operation of prescription. The California doctrine of correlative rights applicable to percolating waters imposes obligations on overlying users of percolating waters to share the burdens when there is not enough for all such users. Fundamental principles of ground water law are hereafter briefly discussed.

Rule Established by California Court Decisions

The courts have differentiated between waters flowing in subterranean streams through known and definite channels and percolating waters. Ground waters flowing through definite underground streams are subject to the same laws as streams with surface flows. The English common law rule of absolute ownership of percolating waters on the part of the landowners was abrogated in 1903 by the California Supreme Court. Katz v. Walkinshaw, 141 Cal. 116. The principles therein declared, and as developed in subsequent decisions, have come to be known as the California doctrine of correlative rights. The correlative doctrine of rights of landowners overlying percolating waters is comparable in many respects to the doctrine of riparian rights of owners of lands contiguous to water courses. The two doctrines became more closely analogous after adoption of the constitutional amendment in 1928, Calif. Const. Art. XIV, Sec. 3, which imposed reasonable use upon riparian as well as ground water uses.

(1) Rule Established in Katz v. Walkinshaw

Both plaintiff and defendant were owners of land in the same artesian area in this case. Defendant had sunk wells and was diverting the ground waters for sale to lands distant from the artesian belt from which the ground waters were derived. Plaintiff had sunk wells for irrigation and domestic uses on his overlying land. Defendant alleged that the ground waters were percolating waters, and that under the common law rule, he had an absolute right to extract therefrom to any extent he saw fit and use the water anywhere irrespective of whether it would result in depriving plaintiff of pumping water for irrigating purposes. The rule summarized in the syllabus of the case follows:

An underground body of water lying in an artesian belt; which does not flow in any defined stream, but is produced by percolation through the saturated soil, and is pressed forward by water accumulating from ravines, canyons, and streams above, pressing down into the soil by percolating, is not a water course, and is not governed by the law of riparian rights.

Each owner of soil lying in a belt which becomes saturated with percolating water is entitled to a reasonable use thereof on his own land, notwithstanding such reasonable use may interfere with water percolation in his neighbor's soil; but he has no right to injure his neighbors by an unreasonable diversion of the water percolating in the belt for the purpose of sale or carriage to distant lands.

The owners of artesian wells sunk in an artesian belt of percolating water, the waters from which are necessary for domestic use and irrigation of their lands, on which are growing trees, vines, shrubbery and other plants of great value, are entitled to an injunction to restrain the diversion of water percolating in the artesian belt, by an owner of land situated in the belt for the purpose of conveying the same to distant lands for sale to the irreparable injury of plaintiffs.

Where the complaint for the injunction states in substance that plaintiffs had wells in their respective tracts, from which water flowed to the surface of the ground which was necessary for domestic use and irrigation of their lands, and that the defendant by means of wells and excavations on his own lands drew the waters from the plaintiffs' lands and conveyed them to distant lands, it states a cause of action for an injunction to restrain the diversion of percolating water; and an averment that the diversion was from an underground stream may be regarded as surplusage.

Such parts of the Common Law of England as are not adapted to our condition, form no part of the Law of this State. The Common Law by its own principle, adapts itself to varying conditions, and modifies its rules so as to subserve the ends of justice under different circumstances, and recognizes the principle embodied in Section 3510 of the Civil Code that, when the reason of a rule ceases so should the rule.

The Common Law rule that percolating water belongs unqualifiedly to the owner of the soil, and that he has the absolute right to extract and sell it, is not applicable to the conditions existing in a large part of this State, where artificial irrigation is essential to agriculture, and artesian wells in percolating belts are necessarily used for that purpose.

The difficulties that the courts will meet in securing persons necessarily using percolating water for irrigation by means of artesian wells from the infliction of great wrong and injustice by its diversion, if property right therein is recognized, cannot justify the court in abandoning a task as impossible. The courts can protect this particular species of property in water as effectually as water rights of any other description.

The rules respecting priority of appropriation and correlative rights in regard to the appropriation of percolating water include the right to appropriate any surplus not needed for use by well owners on their lands, and an equitable adjustment of disputes between overlying landowners, where the supply is insufficient for all, and proper rules relative to injunctions and the remedy at law should be applied to the solution of questions arising in the courts as to such waters.

(2) Extension and Clarification of Rule

California Supreme Court decisions in six cases during the six-year period following Katz v. Walkinshaw extended and clarified the correlative doctrine as applied to percolating waters. These cases were:

McClintock v. Hudson, 141 Cal. 275 (1903)

Cohen v. La Canada Land and Water Co., 142 Cal. 437 (1904)

Montecito Valley Water Co. v. Santa Barbara, 144 Cal. 578 (1904)

Verdugo Canyon Water Co. v. Verdugo, 152 Cal. 655 (1908)

Burr v. Maclay Rancho Water Co., 154 Cal. 428 (1908)

Hudson v. Dailey, 156 Cal. 617 (1909)

The rule laid down in McClintock v. Hudson is summarized in the syllabus as follows:

> Under the rule established in Katz v. Walkinshaw with respect to percolating water, it is not lawful for one owning land bordering on a stream to excavate in his land, to intercept percolating water therein, and apply it to any use other than its reasonable use upon the land from which it is taken, if he thereby diminishes the stream to the damage of others having rights therein.
>
> An owner of land adjoining a stream, who, by excavations in his land, takes percolating water therefrom, and to that extent diminishes the stream, has no greater rights to the water thus taken from the stream than he would if the water were taken directly from the stream.
>
> It was the duty of the court to have found from the evidence that the taking out of the water through plaintiff's excavation and tunnel caused a diminution of the stream, and then to ascertain and state the amount of diminution.

A further clarification of the rule as to interconnected surface and ground waters was made in Cohen v. La Canada Land and Water Co., which is summarized in the syllabus as follows:

> When water percolating in springs on public land above plaintiff's land, and flowing therefrom, was appropriated for use on plaintiff's land by means of pipes, plaintiff may recover damages for the diversion of the water from such springs for sale and use on distant lands, with consent of a subsequent owner of the land on which the springs were situated, and may enjoin such diversion to plaintiffs injury.

The following excerpt from the foregoing decision is informative:

> "The case of Katz vs. Walkinshaw, decided Nov. 28, 1903, establishes a rule with respect to waters percolating in the soil, which makes it to a large extent immaterial whether the waters in this land were or were not a part of an underground stream, provided the fact be established that their extraction from the ground diminished to that extent, or to some substantial extent, the waters flowing in the stream. By the principles laid down in that case it is not lawful for one owning land bordering upon or adjacent to a stream to make an excavation in his land in order to intercept and obtain the percolating water, and apply such water to any use other than its reasonable use upon the land from which it is taken, if he thereby diminishes the stream and causes damage to parties having rights in the water there flowing."

The syllabus summary of the rule laid down in the case of Montecito Valley Water Co. v. Santa Barbara follows:

> One who has no legal right to the surface flow of a stream cannot, as against appropriator or riparian proprietor entitled to such flow, by indirection obtain the right to divert any part thereof by a subterranean tapping and taking thereof.
>
> The court, in an action to enjoin the diversion of water and to recover damages for a wrongful diversion, must pass upon all the issues involved in the action; and it has no right on account of the difficulty of decision, to relegate any part of the issues to future litigation. It must not only decide upon the amount of water diverted, but must also determine the amount of damages thereby sustained by the plaintiff.
>
> The plaintiff under an averment of ownership, may prove a prescriptive title, and such proof will support a finding of ownership, which includes all probative facts, and need not specify ownership by prescription.

A rule was established in the case of Verdugo Canon Water Co. v. Verdugo providing for apportionment of available ground water supply where demand exceeded the yield. The rule laid down as summarized in the syllabus in this case follows:

> It was an error of the court not to find specifically whether or not the amount of water pumped by each party was the proportion of the underground flow to which such party was entitled, or whether or not any of that pumped on the land above constituted part of the water to the flow of which the land below was entitled, or not to attempt to fix the comparative rights of the parties to the surface and underground flow, or to the surplus flow.
>
> A finding that none of the parties has ever taken and used more water than was reasonably necessary for the proper irrigation of his land, and that none has had enough for that purpose, does not show a justification for such use. Necessity is not the sole measure of comparative right in such cases.
>
> In order to support an injunction, it is not necessary that the plaintiffs should be able to prove with absolute precision the extent of their injury from wells sunk by the defendants.

The following excerpt from the foregoing decision relates to limitation by the court of draft to safe yield:

> "A decree merely fixing the proportion of the underground supply to which each was entitled would be of no benefit, for it would not enable either party to know the amount which he could pump. The total supply can only be determined by the court after a consideration of such evidence as it can obtain on the question. It will be necessary for the court to determine from the evidence the total amount of the underflow available for a decision and to determine the share of each by fixing a positive quantity which each may take as his proper proportion of the whole."

A further crystallization of the rule of limitation of an overlying landowner to his reasonable proportion of the available water supply, if there is not enough for all, was made in the case of Burr v. Maclay Rancho Water Co. This case also provided for protection of rights of overlying landowners not using water from prescription by appropriators through resort to declaratory injunction. The rule laid down is summarized in the syllabus of the decision on the first appeal as follows:

> Different owners of separate tracts of land, situated over common strata of percolating water, may, each upon his own lands, take by means of wells and pumps from the common strata, such quantity of water as may be reasonably necessary for beneficial use upon his land, or his reasonable proportion of such water, if there is not enough for all; but one cannot, to the injury of the other, take such waters from the strata and conduct it to distant lands not situated over the same water-bearing strata.
>
> As between an appropriator of percolating water for use on distand land, and an owner of land overlying the water-bearing strata, who was using the water on his land before the attempt to appropriate, the rights of the overlying landowner are paramount. Such rights, however, extend only to the quantity of water that is necessary for use on his land, and the appropriator may take the surplus.
>
> After an appropriator of water from a common water-bearing strata has begun to take water therefrom to distant lands not situated over the strata, for use on such distant lands, the owner of other overlying land upon which he has never used the water, may invoke the aid of a court of equity to protect him in his right to thereafter use such water on his land, and thus prevent the appropriator from defeating his right, or acquiring a paramount right by adverse use, or by lapse of time. Such an appropriation for distant lands is subject to the reasonable use of the water on lands overlying the supply, particularly in the case of persons who have acquired the lands because of these natural advantages.
>
> As against the owners of such overlying lands, either those who have used the water on their lands before the attempt to appropriate, or those who have not previously used it, but who claim the right afterward to do so, the appropriator for use on distant land has the right to any surplus that may exist. If the adjoining overlying owner does not use the water, the appropriator may take all the regular supply to distant land until such land owner is prepared to use it and begins so to do.
>
> In controversies between the owners of such overlying lands, and an appropriator of water for use on distant lands, the court has the power to make reasonable regulations for the use of the water by the respective parties, fixing the times when each may take it and the quantity to be taken, provided they be adequate to protect the person having the paramount right in the substantial enjoyment of that right and to prevent its ultimate destruction.

A summary of the rule laid down relative to prescription and the running of the statute of limitations is set forth in the syllabus of Hudson v. Dailey, which follows:

> Where an upper adverse claimant had diverted the waters of the creek for many years by means of a dam and ditch, and sunk wells more than five years before suit to protect his appropriation and had used such wells adversely to the plaintiff and to the knowledge of the plaintiff for the full period of limitation and pleaded the bar of the statute, the action is clearly barred as to him.
>
> The running of the statute of limitations in favor of the defendant pleading the statute was not deferred until the extraction of the water had begun to diminish the flow at plaintiff's dam, but ran from his diversion where it appears that plaintiff had knowledge of the flow from the wells immediately and that it would tend to diminish such flow, and that the effect was immediately precaptible.

There has been no substantial change since 1909 in the doctrine of correlative rights as established, clarified and crystallized in the seven decisions of the Supreme Court of California as hereinbefore summarized. The rule of Katz vs. Walkinshaw has been consistently applied to controversies between landowners overlying percolating waters in the following cases:

Newport v. Temescal Water Co., 149 Cal. 531 (1906)

Barton v. Riverside Water Co., 155 Cal. 509 (1909)

Lemm v. Rutherford, 76 Cal. App. 455 (1926)

Revis v. Chapman and Co., 130 Cal. App. 109 (1933)

Corona Foothill Lemon Co. v. Lillibridge, 8 Cal. (2d) 522 (1937)

Mention should also be made of additional rules supplementing the correlative doctrine, which may be applicable to a solution of the local ground water problems. In the above mentioned case of Barton v. Riverside Water Co., it was held that the drilling of new wells to replace others which had begun to fail was a mere change in the place of diversion, and where there was no question as to the right to extract and no greater quantity was being pumped, such change was permissible provided no material injury resulted to others legally entitled to take. It was held in Lodi v. East Bay Municipal Utility District, 7 Cal. (2d) 316 (1936) that the place of diversion cannot be changed to an entirely different tract when to do so will adversely affect the rights of other owners.

The above mentioned Lodi case further held that the court has power to adopt and enforce a physical solution even if the parties cannot agree upon one. An excerpt from the decision follows:

> "Other suggestions as to possible physical solutions were made during the trial. The trial court apparently took the view that none of them could be enforced by it unless the interested parties both agreed thereto. This is not the law. Since the adoption of the 1928 constitutional amendment, it is not only within the power but it is also the duty of the trial court to admit evidence relating to possible physical solutions, and if none is satisfactory to it to suggest on its own motion such physical solution. (Tulare Irr. Dist. v. Lindsay-Strathmore Irr. Dist., 3 Cal. (2d), p. 574.) The court possesses the power to enforce such solution regardless of whether the parties agree. If the trial court desires competent expert evidence on this or any other problem connected with the case, it possesses the power to refer the matter to the division of water rights (now Division of Water Resources) of the board of public works, or to appoint it as an expert."

It was held in San Bernardino v. Riverside, 186 Cal. 7 (1921), that an extraction of percolating waters for municipal uses is an appropriation. Ground water underlying a city was held to be private property owned by the property owners, and not by the city, which in this instance had not condemned. However, it was held in Coachella Valley County Water District v. Stevens, 206 Cal. 400 (1929), wherein the statute creating said district was controlling, that the district was entitled to represent the interests of individual owners within the district. It was held in Los Angeles v. Glendale, 23 Cal. (2d) 68 (1943) that Los Angeles had not abandoned foreign waters which had been imported and spread to underground storage for later recapture.

(3) Summary

The rule of correlative and reasonable use on areas overlying percolating waters governs in California. Ground water may be appropriated or exported only if not needed on overlying lands, but an unresisted appropriation may ripen into a prescriptive right, which may become superior in priority and in right to the correlative rights of the overlying land owners.

It has been recognized that ground water and surface water in the same stream system may be related and therefore that pumping ground water from a point upstream could be enjoined if it unreasonably depleted surface flow below; and conversely, an upstream taking of surface flow could be enjoined if it unreasonably depleted the underground supply at a point downstream. The laws relating to percolating waters in California are all court made, with the exception of items relating to the regulation and control of flowing artesian wells, as set forth in Sections 300 to 311, inclusive, of the Water Code, and the right to withdraw water stored in the ground as provided in Section 1242 of said Code.

A concise statement of the California law of water rights, including the rule of correlative rights in making use of percolating waters, is set forth in "Selected Problems in the Law of Water Rights in the West", by Wells A. Hutchins, LL.B., (1942) on pages 188 and 189. An excerpt therefrom follows:

> "1. A constitutional amendment approved in 1928 limits the right to water from any natural stream to reasonable methods of diversion and reasonable, beneficial uses.
>
> "2. The appropriation statute applies to waters in subterranean streams flowing through known and definite channels. There are no other statutes relating to the ownership or appropriation of ground waters, other than with respect to the right to withdraw water stored in the ground.
>
> "3. A statute regulating artesian wells and use of artesian water in the interest of conservation has been upheld under the State police power. A county ordinance regulating pumping from all wells has been similarly upheld. (Note: Ex Parte Elam, 6 Cal. App. 233, and Ex Parte Maas, 219 Cal. 422.)
>
> "4. The laws applying to surface streams have been consistently applied to defined underground streams. The underflow of a surface stream is a part of the stream, and holders of riparian and appropriative rights are protected from interference with so much of the subflow as is necessary to support the surface stream and maintain its volume.
>
> "5. Percolating waters, including artesian waters, are subject to the doctrine of correlative rights, an adaptation of the American doctrine of reasonable use. This rule has superseded the earlier rule of absolute ownership of percolating waters by owners of overlying lands.
>
> "6. The correlative doctrine recognizes equal rights on the part of owners of overlying lands, to waters in the common subterranean strata, for use on such lands; and equal rights as between such owners and owners of land riparian to a stream, the waters of which are part of a common supply. When the supply is insufficient for all, each is entitled to a fair and just proportion, which the court has power to determine from the evidence and to regulate. No case has been found in which an apportionment as between all landowners or water users claiming rights in a common supply has actually been made by the court, although a comprehensive determination in one area is now in progress. As between such

landowners, priority of use on overlying lands is not a factor.

(Note: Decree has been entered in this case, Pasadena v. Alhambra, Superior Court, Los Angeles County, No. Pasa-C-1323, referred to by Mr. Hutchins, and watermaster service has been rendered by the Division of Water Resources in the Raymond Basin Water Master Service Area, continuously since July 1, 1944. A second case involving a comprehensive determination of rights to ground water in the West Coast Basin was referred to the Division of Water Resources under the court reference procedure in July, 1946.)

"7. The right of an owner of overlying land to the use of percolating waters on his land is paramount to that of one who takes from the same underground stratum for distant use. However, an appropriator may take any surplus above the reasonable, beneficial needs of such overlying lands. Pending use on overlying lands, an appropriator may take the 'regular' supply to which these lands would be entitled; the owner of the overlying land being entitled to a declaratory decree to protect his right against loss and to prevent destruction of the source of supply. Rights to percolating waters may be acquired by prescription against the rights of owners of overlying lands who fail to protect such rights.

"8. The constitutional amendment of 1928 has been upheld as a new State policy bringing all water users under the rule of reasonableness. This applies to all water rights, whether grounded on the riparian right, or the analogous right of the owner of overlying land, or the percolating water right, or the appropriative right.

"9. Rights to all waters, surface and subterranean, which form part of a common supply, are correlated under the modified common law doctrines of ownership and use, upon which the doctrine of appropriation is superimposed; all subject to the test of reasonable, beneficial use."

Anticipated Legal Problems

It may be anticipated that certain legal problems will arise in connection with development of various methods of conservation available for salvage of surface waste from the Salinas Basin to Monterey Bay. Consideration should be given to the legal aspects, insofar as possible, as a preliminary step to the solution of the water problems.

(1) Rights of Way and Financing

As previously set forth in Chapter X, any complete solution of overdraft problems in the basin will necessitate an extensive diversion system from the Salinas River. This will involve rights of way through several holdings. Funds must be raised to finance construction, operation, and maintenance. These matters necessitate creation of a local water authority or public district endowed with the power of eminent domain and with the power to levy and collect assessments.

Reference is made to a mimeograph publication by the Division of Water Resources, dated October, 1941, entitled "General Comparison of California Water District Acts" and supplement attached thereto. This publication summarized important features of 33 acts and notes other acts recently enacted, including the San Luis Obispo County Flood Control and Water Conservation District

Act, Chapter 1294, Statutes of 1945. One or more of these prior enactments suited to local conditions could be used as a pattern for legislation creating a water authority, which would provide the mechanics to proceed with the solution of water problems involving both water conservation and flood control.

(2) Comprehensive Adjudication Under Water Code

An increase in irrigation efficiency resulting in general conformity with good irrigation practices prevailing in the Salinas Valley would do much to relieve present overdraft on the 180-foot aquifer in the Pressure Area, and to retard current marine intrusion. It appears however that this would have little effect on overdraft in the East Side Area. Increase in irrigation efficiency is a vital step toward conservation of quality of ground water throughout the basin, which is threatened by excessive leaching of top-soil.

An expeditious and certain method available for eliminating extractions in excess of beneficial requirement, and obtaining uniform observance of the rule of reasonable use as enjoined by Section 3, Article XIV of the Constitution, is through a comprehensive determination of rights to extract ground water under the court reference procedure. (Sections 2000 to 2050, inclusive, of the Water Code.) The constitutional provision provides in part as follows:

> "that because of the conditions prevailing in this tate the general welfare requires that the water resources of the state be put to beneficial use to the fullest extent of which they are capable, and that the waste or unreasonable use or unreasonable method of use of water be prevented, and that the conservation of such waters is to be exercised with a view to the reasonable and beneficial use thereof in the interest of the people and for the public welfare".

The court reference procedure permits the reference of any water right case to the Department of Public Works, acting through the State Engineer, for investigation and report upon any or all of the issues. The procedure has been recommended to the superior courts in many recent water law decisions of the Supreme Court. Wood v. Pendola, 1 Cal. (2d) 435 (1934); Peabody v. Vallejo, 2 Cal. (2d) 351 (1935); Tulare Irr. Dist. v. Lindsay-Strathmore Irr. Dist. 3 Cal. (2d) 489 (1935); Lodi v. East Bay Mun. Utility Dist., 7 Cal. (2d) 316 (1936); Rancho Santa Margarita v. Vail, 11 Cal. (2d) 501 (1938); Meridian Ltd. v. San Francisco, 13 Cal. (2d) 424 (1939) The details of the procedure have been reviewed and approved in Fleming v. Bennett, 18 Cal. (2d) 518 (1941).

The reference of an action to the Department of Public Works, first involves the filing of a complaint in the superior court. Upon filing of such complaint, or at any time thereafter before judgment, the court may order the reference. Issues may be joined before or after the order of reference, and in either event such issues or physical facts as are involved in the suit and have been referred, are within the scope of the reference. The order is in no way dependent upon consent of the parties.

Several benefits would be derived from a comprehensive determination of rights to extract ground water in the basin other than elimination of extractions in excess of beneficial requirement. It would afford a basis for assessment, pro rate in accord with benefits received, of cost of providing a water supply necessary to enable a complete solution of water conservation problems. It would also stop the running of the statute of limitations and prevent the impairment of legal rights of claimants to water whose rights may be in the process of being adversed

by prescription. A comprehensive adjudication would give stability to water right titles and provide for orderly progress of development of a complete solution of water conservation problems.

In the absence of a comprehensive determination of rights to take ground water under existing conditions, the extent to which each individual water user should participate in the solution of water conservation problems, in order to maintain an adequate supply of good quality to meet full requirements, would remain unknown. Appropriators or exporters taking percolating water from the basin supply for beneficial uses for more than five years, in the absence of a declaratory decree to the contrary, would be in a position to claim rights paramount to the correlative rights of owners for use on overlying lands. Increases within the past five years in appropriations or exportations from the basin supply of percolating waters, in an area of overdraft, would be subject to attack by overlying landowners. Likewise any such future increase in appropriations or exportations under overdraft conditions would be subject to attack.

No court decision on ground water percolation has been noted relative to the tendency of overdraft conditions such as in the East Side Area to deflect ground water flow from the Pressure Area to make up the deficiency in the natural tributary supply to the former area. It may be argued with considerable support from many California ground water decisions that all interconnected water in a basin or stream system are parts of the common supply and the rights of all owners to take for use on their respective overlying lands are correlative. However, insofar as the correlative doctrine of percolating waters is based on analogy to the riparian doctrine of surface flow, a contrary contention may be supported. The lands of owners in the East Side Area are either riparian to streams originating on the Gabilan Range or overlie ground waters replenished by percolation therefrom. Lands in the East Side Area do not naturally overlie percolating waters from the Salinas River but overdraft conditions serve to artificially induce river percolation to flow through water-bearing strata to the area thereby diminishing the ground water flow through the lands naturally overlying river influence. Insofar as river percolation is induced into the East Side Area, it may therefore be contended that such inducement is analogous to an appropriation or exportation rather than the exercise of an overlying or riparian right. Rancho Santa Margarita v. Vail, 11 Cal. (2d) 501 (1938); Holmes v. Nay, 186 Cal. 231 (1921); Anaheim Union Water Co. v. Fuller, 150 Cal. 327 (1907).

The costs of a water right determination proceeding are equitably apportioned against the water right owners included in the action. No fee is charged, but actual expenses incurred by the referee are chargeable as costs. The Division of Water Resources has accurate data on costs in adjudications it has completed. The unit cost of an adjudication depends upon so many variable factors that the cost of a proposed adjudication cannot be readily estimated from cost data already accumulated without preliminary field and office investigation. One of the most important factors affecting the cost of a proposed adjudication is the extent of necessary information previously obtained and available. A large part of the information collected by the Division of Water Resources in 1931-32 and 1944-45 and by the County of Monterey between 1933 and 1944 on ground water conditions in the basin is pertinent and would be usable in ascertainment of relative rights to take ground water.

The statutory adjudication procedure set forth in Sections 2500 to 2865, inclusive, of the Water Code is limited to determination of rights in and to the use of flow in surface streams and subterranean streams flowing through known and definite channels. Underground water is presumed to be percolating water, and one who claims rights in a flowing underground stream has the burden of showing its existence. Arroyo Ditch and Water Co. v. Baldwin, 155 Cal. 280; Los Angeles v. Pomeroy, 124 Cal. 597; Southern Pacific R. Co. v. Dufour, 95 Cal. 615; Hanson v. McCue, 42 Cal. 303.

(3) Use of Underground Reservoirs

A complete solution of water conservation problems in the Salinas Basin, as previously explained, may include utilization of two natural underground reservoirs. One of these situated in the Forebay Area has a large surplus of unused underground storage and the other in the East Side Area has empty capacity for storage. In regards the right to use underground reservoirs where storage capacity already exists and can readily be made available, a case in point is Los Angeles v. Glendale, 142 Pac. (2d) 289 (1943). It is stated at page 294 in that decision as follows:

> "It would be as harsh to compel plaintiff to build reservoirs when natural ones were available as to compel the construction of an artificial ditch beside a streambed."

The proposed plan, involving utilization of unused underground storage, includes compensation of overlying owners in the Forebay Area for increased costs of operation, although estimated ultimate demand would require use only within the 60-foot zone below ground surface. It was stated in Peabody v. Vallejo at page 496, 40 Pac. (2d) as follows:

> ". . .The correct rule is stated with its appropriate limitations in the italicized words in the following language of the District Court of Appeal in Waterford I. Dist. v. Turlock I. Dist., 50 Cal. App. 213, at page 221, 194 P. 757, 761: 'The mere inconvenience, or even the matter of extra expense, within limits which are not unreasonable, to which a prior user may be subjected, will not avail to prevent a subsequent appropriator from utilizing his right.'" (Note: Emphasis was supplied by the Court)

Prior users are subject to extra expense within reasonable limits and it might be ruled by a court that the item of additional cost of pumping under existing plants in the Forebay Area should be borne in whole or in part by the users in that area rather than by users who would receive direct service from substitute water.

APPENDIX A

TABLES 1 to 36, INCLUSIVE

TABLE 1

Valley Floor Inflow--Salinas Basin
Tributary to Alluvial Fill--1929-30 to 1944-45

ARROYO SECO RUNOFF INDEX		81	68	102	130	292	143	18.5	248
Area Embraced	Area Square Miles	Acre-feet per Seasonal Year							
		1944-45	1943-44	1942-43	1941-42	1940-41	1939-40	1938-39	1937-38
McCoy Canyon to Henry Sands Canyon	13.9	290	190	420	600	1,580	670	0	1,320
Bryant Canyon to Shirtail Canyon	21.2	450	300	640	910	2,420	1,020	0	2,010
San Carlos to Pinolito Canyon	29.1	610	410	870	1,250	3,320	1,400	0	2,760
Sweetwater to Redwood Canyon	94.8	1,990	1,330	2,840	4,080	10,810	4,550	0	9,010
Deadman's Gulch to Hare Canyon	94.9	1,990	1,330	2,850	4,080	10,820	4,560	0	9,020
Mahoney to Lowes Canyon	21.3	450	300	640	920	2,430	1,020	0	2,020
San Marcos Creek	31.3	8,240	7,460	9,390	10,700	18,260	11,320	2,890	16,230
Lower San Antonio Hames Creek	87.0	23,060	20,880	26,270	29,930	51,070	31,670	8,090	45,410
Foothills South of Johnson Canyon	125.5	2,510	1,760	3,760	5,400	14,430	6,150	0	11,800
Santa Rita Foothills	19.6	390	270	590	940	2,260	960	0	1,840
Gabilan Creek to Johnson Canyon	107.2	*2,360	1,500	3,970	6,540	25,190	7,830	0	19,720
San Lorenzo Creek	234.0	7,960	5,380	12,170	*22,060	*68,090	*16,850	0	51,480
Estrella Creek	954.0	20,030	13,360	28,620	44,020	*111,700	* 5,220	0	90,630
Salinas River above Paso Robles	389.0	*48,220	*54,170	*215,000	*85,610	*332,400	*71,210	36,180	203,060
Nacimiento River	342.6	*169,300	*164,300	*296,800	*253,800	*604,000	*304,000	53,450	517,300
San Antonio River at Pleyto	283.0	* 58,540	* 45,080	*91,680	*91,370	*280,000	*116,700	*6,840	*212,800
Arroyo Seco	231.0	*105,000	* 88,640	*132,700	*169,200	*380,200	*186,600	*24,100	*323,700
Chalone Creek	141.3	8,050	6,080	10,460	12,720	18,500	13,560	0	17,520
Pancho Rico Creek	61.4	3,500	2,640	4,540	5,530	8,040	5,890	0	7,610
Indian Valley & Vineyard Canyons	136.2	7,760	5,860	10,080	12,260	17,840	13,080	0	16,890
Huernuero Creek	155.8	8,880	6,700	11,530	14,020	20,410	14,960	0	19,320
Garrissere Gulch to 7-Wells Canyon	18.1	2,410	2,010	2,990	3,620	7,060	3,960	0	6,150
Kent Canyon to Reliz Creek	85.0	11,310	9,440	14,020	17,250	33,150	18,610	0	28,900
No. of Arroyo Seco to So. of Toro Creek	62.9	8,350	6,970	10,360	12,750	24,490	13,750	0	21,350
Foothills South of Toro Creek	150.0	12,460	9,160	16,960	21,910	43,080	24,020	0	37,830
Toro Creek	42.6	3,530	2,600	4,800	6,200	12,200	6,800	0	10,700
Foothills North of Toro Creek	18.1	1,500	1,100	2,040	2,640	5,200	2,900	0	4,600
Total Tributary Inflow	3,950.5	519,000	459,000	917,000	840,000	2,109,000	889,000	132,000	1,691,000
Precipitation on Alluvium	374.0	214,000	220,000	234,000	289,000	400,000	300,000	174,000	299,000
Estimated Marine Intrusion	---	12,000	11,000	10,000	8,000	0	8,000	10,000	0
Estimated Lateral Percolation	---	Slight	Slight	Slight	2,000	6,000	Slight	Slight	Slight
Total Inflow	4,325	745,000	690,000	1,161,000	1,139,000	2,515,000	1,197,000	316,000	1,990,000

*Measured Discharge.

TABLE 1 Cont'd.

Valley Floor Inflow--Salinas Basin
Tributary to Alluvial Fill--1929-30 to 1944-45

ARROYO SECO RUNOFF INDEX	114	93	71	59.5	15	- From DWR 1933 Report -			99
	Acre-feet per Seasonal Year								
Area Embraced	1936-37	1935-36	1934-35	1933-34	1932-33	1931-32	1930-31	1929-30	16-Year Average
McCoy Canyon to Henry Sands Canyon	500	380	220	140	0	1,700	0	0	500
Bryant Canyon to Shirtail Canyon	760	570	340	210	0	1,900	0	0	720
San Carlos to Pinolito Canyon	1,050	790	470	290	0	2,500	0	0	980
Sweetwater to Redwood Canyon	3,410	2,560	1,520	950	0	8,500	0	0	3,200
Deadman's Gulch to Hare Canyon	3,420	2,560	1,520	950	0	11,700	0	0	3,400
Mahoney to Lowes Canyon	770	580	340	210	0	2,600	0	0	770
San Marcos Creek	9,950	8,590	7,650	6,870	2,390	11,700	600	3,700	8,500
Lower San Antonio & Hames Creek	27,840	24,980	21,400	19,230	6,700	24,900	600	5,300	23,000
Foothills South of Johnson Canyon	4,640	3,390	2,010	1,250	0	3,250	0	0	3,770
Santa Rita Foothills	720	540	310	190	0	900	0	0	620
Gabilan Creek to Johnson Canyon	5,150	3,480	1,710	1,070	0	12,200	0	0	5,600
San Lorenzo Creek	14,270	10,060	5,850	3,740	0	35,100	500	2,800	16,000
Estrella Creek	34,340	25,760	15,260	9,540	0	39,100	0	0	27,300
Salinas River above Paso Robles	124,500	111,250	95,690	85,970	29,950	132,600	6,800	38,800	104,500
Naciemento River	254,200	213,100	169,600	147,000	44,540	196,000	18,200	69,500	217,200
San Antonio River at Pleyto	* 80,050	* 57,490	* 42,250	* 30,800	* 3,790	* 82,000	* 2,040	*17,500	* 76,180
Arroyo Seco	*148,500	*120,600	* 92,150	* 77,400	*19,500	*132,000	*12,200	*46,800	*128,700
Chalone Creek	11,590	9,470	6,640	4,520	0	21,200	300	1,700	8,900
Pancho Rico Creek	5,030	4,110	2,890	1,960	0	9,200	100	700	3,800
Indian Valley & Vineyard Canyons	11,170	9,130	6,400	4,360	0	19,200	200	1,000	8,400
Huerhuero Creek	12,780	10,440	7,320	4,990	0	15,900	0	0	9,200
Garrissere Gulch to 7-Wells Canyon	3,290	2,750	2,080	1,700	0	6,100	300	1,900	2,900
Kent Canyon to Reliz Creek	15,470	12,920	9,770	7,990	0	34,200	1,900	10,700	14,000
No. of Arroyo Seco to So. of Toro Creek	11,430	9,550	7,220	5,900	0	24,900	1,400	7,800	10,400
Foothills South of Toro Creek	19,360	15,010	10,060	6,750	0	23,700	0	700	15,000
Toro Creek	5,500	4,260	2,850	1,900	0	14,500	800	4,400	5,100
Foothills North of Toro Creek	2,300	1,800	1,200	800	0	900	0	0	1,700
Total Tributary Inflow	812,000	666,000	515,000	427,000	107,000	868,000	46,000	213,000	701,000
Precipitation on Alluvium	308,000	224,000	277,000	121,000	152,000	280,000	142,000	195,000	239,000
Estimated Marine Intrusion	3,000	4,000	5,000	6,000	7,000	0	7,000	5,000	6,000
Estimated Lateral Percolation	Slight	Slight	Slight	Slight	Slight	Slight	Slight	Slight	500
Total Inflow	1,123,000	894,000	797,000	554,000	261,000	1,148,000	195,000	413,000	946,000

*Measured discharge.

TABLE

Pumping Plant Data in Gallon [illegible] with Water-Level
Overall Efficiency of Plants and Specific Capacity of Wells

Well Number	Date Tested	Meter H.P.	Depth to Static Water Level Feet	Total Lift - Feet	Capacity G.P.M.	Specific Capacity G.P.M. per Ft. Drawdown	KWH per Acre-Foot Pumped	Overall Efficiency Per Cent
1-B-3	6/25/45	15	19.4	40.8	680	11[illegible]	[illegible]4	1[illegible]
1-B-4	6/26/45	15	24.8	52.[illegible]	[illegible]17	14[illegible]	[illegible]1	[illegible]5
1-B-14	6/26/45	15	15.6	46.6	[illegible]07	---	92	52
1-B-31	10/19/47	25	17.1	47.7	1,[illegible]6	---	[illegible]2	41
	4/11/45	20	----	----	1,[illegible]	---	73	--
1-B-32	1[illegible]/8/43	75	15.7	1[illegible]0.7	1,[illegible]2	---	--	5[illegible]
1-B-34	1944	15	14.2	13[illegible].[illegible]	147	14.4	37[illegible]	36
1-B-43	6/28/45	15	----	32.[illegible]	[illegible]30	---	[illegible]5	4[illegible]
1-B-50	7/19/43	25	----	36.6	1,11[illegible]	---	[illegible]1	46
	6/25/45	25	----	39.4	886	---	95	42
3-B-[illegible]	2/25/42	25	15.7	71.1	515	1[illegible].1	--	1[illegible].[illegible]
1-C-18	9/19/45	1[illegible]	----	47.7	59[illegible]	---	77	63
1-C-19	6/23/45	[illegible]	23.5	58.9	708	82.3	172	75
1-C-27	6/29/45	15	18.[illegible]	49.8	710	24.6	[illegible]2	55
1-C-45	9/11/45	2[illegible]	2[illegible].[illegible]	41.4	677	44.7	112	8[illegible]
2-C-5	12/ 2/37	25	18.[illegible]	65.1	795	---	13[illegible]	[illegible]4
2-C-73	9/20/45	25	----	39.7	882	---	10[illegible]	37
2-C-75	9/22/45	15	[illegible]0.7	44.4	583	45.5	14[illegible]	32
2-C-96	1945	20	26.8	41.[illegible]	851	81.[illegible]	--	47
2-C-126	9/23/42	40	27.7	73.6	1,510	34.4	111	67.[illegible]
3-C-3	9/24/42	40	116.0	189.0	668	9.5	283	67.[illegible]
3-C-4	7/14/44	40	----	179.[illegible]	660	---	291	65
3-C-6	10/19/43	25	34.1	122.[illegible]	242	2.8	478	26
3-C-9	3/25/42	25	78.3	113.5	435	12.3	266	44.3
3-C-14	7/14/44	30	----	174.[illegible]	437	---	297	60
3-C-15	8/26/41	60	----	274.1	426	---	566	49.3
3-C-18	5/27/42	25	41.8	76.3	555	19.5	159	45.[illegible]
	5/24/43	15	----	82.9	567	---	143	59
3-C-20	9/14/44	50	92.2	151.[illegible]	681	11.[illegible]	395	39
3-C-22	8/29/42	30	88.7	152.7	562	9.5	250	62.1
3-C-23	6/11/45	50	----	211.[illegible]	551	---	409	53
3-C-26	7/14/44	40	----	177.[illegible]	570	---	336	54
3-C-35	8/14/43	50	88.[illegible]	110.[illegible]	1,056	91.8	253	44.5
3-C-38	3/24/41	40	92.1	179.3	591	6.9	326	56
3-C-39	8/13/43	50	99.0	129.[illegible]	1,046	52.3	237	47.4
3-C-51m	1941	20	38.7	155.3	350	49.6	244	47.2
3-C-56	7/23/45	25	45.4	63.[illegible]	517	33.6	517	49
3-C-58	6/27/35	20	----	73.2	655	---	147	50.7
3-C-71	5/10/44	50	----	141.0	940	---	247	58
3-C-78	9/18/41	40	----	157.5	550	---	293	54.[illegible]
3-C-80	8/26/41	30	----	140.3	450	---	238	60.2
3-C-93	6/11/43	50	70.3	119.[illegible]	1,160	31.[illegible]	205	59
3-C-95	11/30/37	125	144.3	169.5	2,335	---	273	63.[illegible]
3-C-131	9/22/45	50	----	126.[illegible]	975	---	252	51
4-C-3	7/24/43	60	124.2	160.5	951	42.3	329	49.9
4-C-7	7/28/42	50	120.2	215.7	586	8.1	349	62.7
4-C-8	7/29/42	75	----	180.2	914	---	362	50.6
2-D-13	8/19/43	30	----	48.[illegible]	1,780	---	86	57
2-D-26	7/14/44	25	32.6	41.3	970	118.0	117	38
2-D-27	6/13/45	50	----	53.9	2,560	---	88	62
2-D-28	6/13/45	50	38.0	59.5	2,220	156.0	111	55
2-D-37	6/13/45	30	----	97.[illegible]	920	---	170	58
2-D-48	1944	25	----	123.0	433	---	255	50
2-D-50	5/27/42	15	20.7	50.5	497	19.5	143	35.9
2-D-51	5/27/42	25	17.5	73.1	380	6.1	197	45
3-D-10	7/21/43	20	----	41.4	1,200	---	[illegible]9	4[illegible]
3-D-76	8/22/42	40	40.7	68.7	1,600	72.[illegible]	136	51.[illegible]
3-D-80	6/15/45	25	----	51.0	952	---	1[illegible]	52
3-D-82	6/29/45	20	49.1	59.8	910	96.[illegible]	144	42
3-D-92	7/11/44	35	----	53.[illegible]	1,32[illegible]	---	134	41
3-D-93	7/11/44	25	----	67.2	[illegible]89	---	134	55
3-D-97	5/25/43	20	37.8	43.6	[illegible]20	137.	1[illegible]7	44
3-D-106	5/ 9/44	30	39.6	63.2	1,170	51.7	1[illegible]	[illegible]0
3-D-107	9/15/44	25	----	51.6	[illegible]68	---	11[illegible]	45
3-D-116	5/ 7/44	25	----	65.6	[illegible]40	---	127	53
3-D-125	1945	30	59.5	117.[illegible]	635	77.5	209	57
3-D-126	8/25/41	30	----	5[illegible].7	1,26[illegible]	---	117	4[illegible]
4-D-8	9/24/43	15	121.[illegible]	166.[illegible]	162	27.	[illegible]4[illegible]	4[illegible].7
4-D-11	8/25/42	5[illegible]	----	193.7	57[illegible]	---	[illegible]64	[illegible]1
	7/13/44	75	----	19[illegible].2	1,[illegible]5[illegible]	---	[illegible]15	5[illegible]
4-D-12	8/25/42	50	----	1[illegible]0.	[illegible]71	---	274	[illegible]5.
	6/13/45	5	----	17[illegible].	9[illegible]2	---	[illegible]72	65
4-D-13	7/13/44	3[illegible]	----	10[illegible].	[illegible]67	---	142	6[illegible]
4-D-14	7/13/44	[illegible]	----	1[illegible]8.	[illegible]83	---	244	66
4-D-17	9/13/45	[illegible]5	107.9	141.[illegible]	[illegible]40	2[illegible].5	225	5[illegible]
4-D-31	7/11/45	[illegible]	[illegible]7.	[illegible]9.1	445	.[illegible]	169	5[illegible]
4-D-33	7/27/42	[illegible]	----	85.7	564	---	12[illegible]	45.1
4-D-34	11/24/41	1[illegible]	35.[illegible]	[illegible].3	[illegible]45	[illegible]1.[illegible]	[illegible]9	[illegible].1
4-D-38	6/15/45	1[illegible]	----	[illegible].5	50[illegible]	---	1[illegible]	[illegible]
4-D-[illegible]	7/11/45	[illegible]5	----	[illegible].	1,[illegible]5	---	11[illegible]	[illegible]
4-D-42	1[illegible]/8/43	[illegible]	[illegible]1.	[illegible].1	572	[illegible]7.[illegible]	17[illegible]	[illegible]
4-D-47	[illegible]/[illegible]/41	[illegible]	----	15[illegible].6	347	---	21[illegible]	[illegible].

TABLE 2 Cont'd.

Well Number	Date Tested	Motor H.P.	Depth to Static Water Level: Feet	Total Lift - Feet	Capacity G.P.M.	Specific Capacity G.P.M./Foot Drawdown	KWH per Acre-foot Pumped	Overall Efficiency Per Cent
4-D-40	7/23/43	20	69.8	142.0	243	34.8	349	42
4-D-44	7/14/44	30	----	63.3	770	---	123	52
4-D-45	7/13/44	20	----	70.4	530	---	181	40
4-D-46	7/13/44	15	----	40.1	500	---	97	42
4-D-47	8/27/42	60	----	221.9	697	---	435	51.8
4-D-50	3/ 3/42	60	115.5	140.3	925	41.1	231	61.7
4-D-53	10/18/43	50	----	153.0	844	---	281	55
4-D-63	3/23/42	30	22.1	70.0	1,300	31.1	137	51.8
4-D-68	9/12/44	75	----	240.0	1,160	---	335	73
4-D-69	9/12/44	75	189.4	227.0	1,080	43.1	397	58
4-D-70	5/12/44	75	----	292.0	930	---	450	65
4-D-71	7/13/44	75	198.0	288.0	900	13.7	446	66
4-D-72	8/30/43	75	----	168.7	1,008	36.0	360	47.7
4-D-73	8/30/43	75	180.0	241.8	994	22.7	378	65.5
4-D-75	10/18/43	100	159.1	191.0	1,020	64.6	373	52
4-D-77	2/ 3/42	50	100.0	133.8	953	47.3	241	55.8
4-D-79	3/ 2/42	60	122.6	162.1	1,030	34.4	265	62.5
4-D-81	(10/27/42	40	89.5	131.0	696	17.7	246	54.1
	(8/16/43	40	89.0	113.9	747	108.0	240	48.7
4-D-85	(10/27/42	50	121.2	182.1	478	12.5	503	36.7
	(8/26/43	50	128.9	172.5	441	10.6	550	32.1
4-D-87	3/24/42	40	16.4	85.9	897	15.3	149	58.7
4-D-88	6/13/45	25	----	84.7	695	---	149	58
4-E-3	6/15/45	20	----	52.9	660	---	132	41
4-E-4) 4-E-4A)	5/28/42	25	13.6	48.6	1,500	---	72	68.7
4-E-5		35	15.5	43.8	1,520	217.0	88	50.8
4-E-10	6/11/45	35	----	81.1	1,530	---	140	59
4-E-13A	9/13/44	30	33.9	63.7	1,140	41.0	123	53
4-E-22	9/29/43	50	73.4	104.4	1,783	302.7	214	49.8
4-E-23	(6/29/42	100	----	141.7	1,750	---	219	65.7
	(8/30/43	100	100.3	158.3	1,229	122.9	306	53
4-E-25	7/23/43	30	----	63.1	1,580	---	91	71
4-E-29	8/21/41	60	----	66.6	2,200	---	133	50.8
4-E-50	7/31/41	50	----	37.1	2,910	---	93	40.6
5-E-2	9/21/45	60	----	243.0	410	---	645	38
5-E-3	4/28/42	75	49.5	72.4	1,699	90.4	249	57.6
5-E-5	9/24/42	50	29.2	52.9	1,590	140.0	117	46
5-E-6	(7/29/41	60	----	220.6	654	---	363	61.8
	(9/21/45	60	139.6	217.0	623	16.0	410	54
5-E-16	6/21/45	20	----	58.5	888	---	114	52
5-E-20	6/12/45	30	----	69.2	1,420	---	106	67
5-E-23	12/ 7/42	75	----	103.6	1,630	---	165	64
5-E-24	(6/ 3/41	75	109.6	158.7	1,400	30.8	219	73.6
	(10/29/42	75	109.0	169.2	1,175	---	249	69.3
5-E-26	7/13/44	50	----	135.0	1,040	---	229	60
5-E-30	7/29/41	60	----	134.2	1,500	---	191	71.8
5-E-33	2/16/42	35	----	37.0	1,320	---	85	44.2
5-E-34	4/ 6/45	30	----	46.7	2,040	---	86	56
5-E-35	6/30/42	40	----	67.4	1,580	---	119	57.8
5-E-37	7/21/43	50	----	53.0	2,800	---	91	60
5-E-38	9/21/45	40	----	80.8	1,010	---	143	58
5-E-50	(3/26/42	30	19.2	83.3	661	23.2	169	50.2
	(9/21/45	30	28.8	88.8	520	18.2	192	45
5-E-56	4/11/45	30	----	101.0	840	---	189	54
5-E-57	3/27/42	35	23.0	28.5	1,320	---	108	27
5-E-59	6/30/42	50	----	46.0	2,060	---	98	47.5
5-E-60A	4/29/42	25	----	48.0	1,740	---	71	68.9
5-E-61	7/21/43	60	31.8	64.6	1,950	64.8	128	51
5-E-70	10/29/41	25	37.4	52.9	1,290	109.0	101	53.7
5-E-72	5/28/43	75	----	41.9	1,080	---	270	78
5-E-73	5/27/43	75	----	169.5	1,320	---	222	63
5-E-76	5/27/43	75	100.5	218.0	1,140	19.0	327	68
5-F-12	4/12/45	25	----	76.4	929	---	123	63
5-F-15	8/27/42	3	18.7	39.8	2,180	141.0	67	60
6-F-1	8/16/43	150	57.7	221.0	1,242	25.2	505	44.8
6-F-2	7/19/43	150	48.5	177.0	2,024	76.4	333	54.4
6-F-3	(5/20/37	150	45.7	218.3	2,015	---	331	67.3
	(7/19/43	150	46.8	106.0	1,629	48.9	342	31.7
6-F-4	8/31/45	150	164.0	285.4	1,132	17.5	460	63.6
6-F-8	8/16/43	Diesel	130.0	254.0	528	13.6	---	36
6-F-9	10/28/42	50	76.1	112.8	1,800	207.0	186	61.5
6-F-10	10/30/42	40	95.1	148.3	818	15.5	248	60.7
6-F-14	11/27/41	100	153.0	181.6	1,510	126.0	314	58.8
6-F-17	10/30/42	75	52.4	98.7	1,515	56.5	174	57.5
6-F-18	5/28/43	50	----	57.1	2,370	---	96	53
6-F-23	5/28/43	60	----	56.6	2,590	---	110	50
6-F-26	(5/24/37	150	4 .7	218.2	2,105	---	335	66.8
	(7/20/43	150	4 .3	120.7	1,808	54.1	329	37.5
6-F-45	5/26/43	125	45.9	71.2	2,940	98.7	193	77
6-F-46	5/12/44	50	----	48.2	1,610	---	125	39
6-F-48	2/16/43	35	36.3	49.8	1,384	142.2	109	47
6-F-51	2/16/43	50	34.5	52.5	1,293	71.7	178	51
6-F-52	7/22/43	60	29.2	79.5	2,210	46.5	145	64
6-F-53	7/22/43	30	----	48.3	1,71	---	94	58
7-F-5	(12/ 9/42	50	52.1	67.4	1,4	127.1	230	34
	(9/ 2/43	75	53.3	157.8	1,941	14.7	361	52.7
7-F-13	9/17/45	75	78.6	161.0	1,870	176.	229	71

Well Number	Date Tested	Motor H.P.	Depth to Static Water Level: Feet	Total Lift - Feet	Capacity G.P.M.	Specific Capacity G.P.M./Foot Drawdown	KWH per Acre-foot Pumped	Overall Efficiency Per Cent
6-G-14	5/11/44	50	----	52.2	2,700	---	79	72
6-G-17	1944	60	29.5	49.3	3,270	174.0	80	63
6-G-25A	7/30/42	40	----	98.5	888	---	195	51.3
7-G-1	7/30/41	100	----	68.8	3,750	---	112	62.3
7-G-3	7/21/43	50	70.7	101.0	1,570	280.0	143	72
7-G-9	9/20/45	25	----	64.4	912	---	---	49
7-G-10	5/11/44	25	----	37.4	1,710	---	56	68
7-G-12	6/ 5/41	25	14.8	24.7	991	160.0	66	37.3
7-G-14	4/29/41	25	13.0	29.1	1,430	147.0	72	41.2
7-G-15	9/21/42	60	88.6	189.7	534	5.6	335	57.6
7-G-17	8/19/43	50	----	----	2,500	---	84	----
7-G-19	8/19/43	50	32.0	45.7	2,600	289.0	84	55
7-G-22	4/ 9/45	50	----	65.4	2,300	---	97	69
7-G-23	5/11/44	30	----	53.4	1,500	---	97	56
7-G-24	8/19/43	50	20.9	25.5	2,820	---	85	----
7-G-25	(6/ 9/43	25	----	46.8	1,450	---	98	48
	(9/29/43	25	----	53.5	1,245	---	113	48.4
7-G-25A	9/29/43	15	21.3	43.8	973	114.4	88	50.5
7-G-26	(11/28/39	60	134.1	179.6	705	---	329	55.6
	(6/ 9/43	60	122.3	154.0	1,220	51.4	261	60
7-G-27	7/ 2/42	75	149.6	189.9	1,340	94.3	280	69.2
7-G-28	7/ 2/42	40	----	32.0	1,560	---	114	28.3
7-G-29	(11/28/39	60	99.8	153.8	1,130	---	269	57.8
	(6/ 8/43	60	----	152.0	1,090	---	270	57
7-G-35	7/20/43	--	42.2	105.8	1,509	90.6	166	70
7-G-36	6/ 8/43	60	66.5	83.1	1,470	201.0	167	51
7-G-45A	10/20/43	40	----	79.5	845	---	176	46
7-G-47	11/27/41	75	121.5	140.8	1,290	76.0	249	57.4
7-G-49	10/20/43	50	----	48.2	1,980	---	96	51
7-G-50	8/19/43	20	----	48.9	1,210	---	90	56
7-G-51	8/19/43	50	30.2	39.7	2,710	301.0	78	52
7-G-52	(11/28/39	50	109.2	128.5	1,450		223	58.5
	(6/ 8/43	75	----	146.0	1,110	---	284	52
7-G-53	4/13/45	150	133.0	159.0	2,360	94.0	270	60
8-G-16	1943	30	----	55.0	1,370	---	98	57
7-H-9	6/10/43	60	87.8	94.3	1,580	282.0	198	49
7-H-21	6/ 9/43	100	53.5	106.0	3,150	113.0	168	64
7-H-22	10/30/40	75	93.7	109.4	1,695	108.0	212	52.3
7-H-25	9/ 3/41	25	----	46.5	898	---	91	52.1
7-H-38	12/ 8/42	100	168.8	262.0	989	16.5	464	57
8-H-14	4/ 4/45	75	----	83.3	1,580	---	169	50
8-H-15	6/14/45	50	----	70.4	1,560	---	129	56
8-H-19	6/11/45	75	78.3	----	2,290	---	159	----
8-H-21	8/26/42	50	40.5	55.7	1,670	204.0	118	47.8
8-H-25	4/14/44	75	----	71.9	3,030	---	120	61
8-H-32	(6/25/36	60	----	232.5	760	---	417	56.8
	(6/ 8/43	60	188.0	214.0	844	88.4	386	57
8-H-38	2/25/41	75	84.8	112.8	1,798	99.0	177	65.3
8-H-40	6/27/45	60	----	79.4	2,130	---	151	54
8-H-48	2/26/41	100	194.7	233.3	1,270	34.4	366	65.2
8-H-50	10/26/38	100	233.9	323.3	930	---	546	60.2
8-H-52	6/23/36	125	216.5	220.2	1,600	433.0	381	58.8
8-H-61	6/ 3/41	40	----	89.1	1,310	---	136	66.6
8-H-62	6/25/41	50	28.5	42.9	3,000	237.0	70	62.2
8-H-63	6/25/41	50	25.4	54.4	3,200	206.0	79	68.8
8-H-71	12/ 8/42	100	114.0	236.0	1,110	9.8	372	65
9-H-1	6/25/41	30	20.8	48.6	1,900	126.0	83	39.2
9-H-3	6/25/41	40	20.0	25.6	2,440	437.0	79	----
9-H-6	8/ 5/43	40	----	29.7	2,360	---	70	43
9-H-8	8/ 5/43	40	----	37.0	2,510	---	68	55
9-H-10	8/ 5/43	50	----	47.0	2,320	---	98	49
9-H-11	8/ 5/43	50	----	50.3	1,730	---	111	46
9-H-12	8/ 5/43	30	----	42.4	2,210	---	73	59
9-I-2	4/ 4/45	50	----	43.0	1,720	---	91	48
9-I-3	9/20/45	30	36.7	67.7	1,370	64.3	104	66
9-I-4	6/14/45	125	----	129.0	3,150	---	200	66
9-I-7	8/ 6/43	15	----	29.6	1,490	---	58	51
9-I-9	8/ 6/43	35	38.2	48.9	2,040	224.0	84	59
9-I-12	8/ 6/43	60	----	61.5	1,900	---	124	51
9-I-13	8/17/43	60	----	55.2	1,980	---	115	49
9-I-15	8/17/43	75	----	86.8	1,560	---	231	38
9-I-19	8/18/43	75	----	----	2,350	---	138	----
10-J-6	4/30/42	15	19.8	33.8	754	80.2	76	45.3
10-J-8	12/18/42	15	----	22.8	1,510	---	47	50.0
10-J-10	(2/ 8/42	25	14.7	27.5	2,120	216.0	53	53
	(12/18/42	25	14.7	32.4	2,045	---	53	53
12-K-3	10/ 2/41	75	72.0	95.0	1,910	434.0	168	57.3
12-K-9	6/ 7/43	25	----	43.0	1,720	---	91	48
12-K-14	(12/ 8/42	75	56.7	66.8	1,530	---	160	42
	(10/20/43	75	60.0	83.1	2,190	221.0	152	56
12-L-7	10/20/43	100	60.8	92.6	1,480	400.0	231	41

TABLE 3

Relationship Between Pressure Surface Fluctuation and Daily Draft on 180-Foot Aquifer During Effective Lag Periods Preceding Each of First Three Measured Positions of Trough in Pressure Surface in 1945 - Recorder Well #2-C-148n

(1) Preceding April 29 Trough Position				(2) Preceding May 20 Trough Position				(3) Preceding June 3 Trough Position			
Date 1945	Pressure Surface Fluctuation-Feet	Combined 10-Hour Rate of Draft c.f.s.	Continuous Flow Equivalent of Daily Draft c.f.s.	Date 1945	Pressure Surface Fluctuation-Feet	Combined 10-Hour Rate of Draft c.f.s.	Continuous Flow Equivalent of Daily Draft c.f.s.	Date 1945	Pressure Surface Fluctuation-Feet	Combined 10-Hour Rate of Draft c.f.s.	Continuous Flow Equivalent of Daily Draft c.f.s.
April 8	0.35	123*	51	April 29	1.90	495	206	May 1	1.50	410	171
9	2.90	685	286	30	3.60	820	341	14	2.75	655	272
10	1.70	450	188	May 1	4.15	900	375	15	2.15	540	225
11	2.10	530	221	2	3.30	760	317	16	1.35	375	156
12	.87	264	110	3	2.80	667	278	17	3.00	705	294
13	1.22	346	144	4	2.30	575	239	18	2.40	590	246
14	1.80	470	196	5	2.00	510	212	19	1.30	365	152
15	1.13	328	137	6	1.10	320	133	20	1.00	295	123
16	3.20	743	310	7	2.00	510	212	21	2.75	655	272
17	3.05	718	299	8	2.60	630	262	22	3.35	770	321
18	2.30	575*	239	9	2.75	655	272	23	4.20	910	380
19	3.84	850*	354	10	2.80	667	278	24	3.45	790	330
20	1.95	500	208	11	3.15	730	304	25	3.45	790	330
21	2.25	563	234	12	2.60	630	262	26	4.05	885	369
22	2.20	555	231	13	1.50	410	171	27	1.65	440	184
23	3.50	800	333	14	2.75	655	272	28	3.50	800	333
24	3.60	820	341	15	2.15	540	225	29	4.20	910	380
25	3.75	840	350	16	1.35	375	156	30	3.30	760	317
26	3.20	743	310	17	3.00	705	294	31	3.30	760	317
27	3.05	718*	299	18	2.40	590	246	June 1	3.35	770	321
28	3.10	725	302	19	1.30	365	152	2	3.45	790	330
	Averages	588	245		Averages	597	248		Averages	665	277

TABLE 4

[illegible]

Culture	Pressure	East Side	Lower Forebay	Upper Forebay	Arroyo Seco	Upper Valley	Total Salinas Valley
	Acres	Acres	Acres	Acres	Acres	Acres	Acres
Irrigated Crops							
Alfalfa	2,201	1,97[illegible]	2,425	[illegible]	[illegible]	[illegible]	14,412
Lettuce	19,457	1,952	2,351	[illegible]	[illegible]	-	24,[illegible]
Truck	9,097	1,414	2,812	2,3[illegible]	[illegible]	1,515	1[illegible],750
Beans	8,926	7,049	[illegible]	2,42[illegible]	[illegible]	6,480	3[illegible],[illegible]75
Sugar beets	3,595	537	1,065	498	173	[illegible]	15,[illegible]
Artichokes	2,942	-	-	-	-	-	[illegible],942
Guayule	2,927	1,59[illegible]	2,462	64	1,057	[illegible]	[illegible],[illegible]3
Seeds	544	109	-	-	-	107	[illegible]
Orchards	250	281	5[illegible]	177	424	1,[illegible]	[illegible]
Grain	151	236	109	-	45	[illegible]9	1,[illegible]
Sub-total	50,090	15,154	14,584	9,052	14,601	21,942	125,423
Irrigable dry farm and grass	12,540	18,815	3,911	271	2,289	14,155	51,[illegible]
Native Vegetation							
Dense trees, etc.	2,669	-	376	477	462	130	4,111
Medium brush, etc.	1,993	-	1,549	1,271	670	8,[illegible]	13,764
Sparse brush, etc.	1,205	-	1,755	855	495	5,346	[illegible],656
Swamp and native grass	2,674	123	91	-	-	-	2,888
Sub-total	8,541	123	3,768	2,603	1,627	13,[illegible]	30,419
Miscellaneous							
Water surface	1,669	-	202	-	-	2,440	4,311
River channel	1,509	-	1,748	1,587	619	2,518	7,981
Waste land	691	-	-	326	1,886	1,354	4,757
Town and farm lots	3,330	970	548	512	205	904	6,469
Roads and railroads	2,610	1,415	771	490	888	1,503	7,677
Sub-total	9,809	2,385	3,269	2,915	3,598	9,219	31,195
Total, Salinas Valley	80,980	36,477	25,532	14,841	22,115	59,073	239,018

TABLE 5

Irrigation of Alfalfa and Ladino Clover in Salinas Valley, as Indicated by a Canvass by the Soil Conservation Service, U.S.D.A., 1945

Area	Total Acreage	Applications		Water Delivered	
		Average Number	Range	Average Total	Range
				Inches	Inches
Pressure	147	6	4 - 8	24.8	20 - 32
Forebay*	38.6	5	5	18	18
Arroyo Seco	247	7	4 - 10	47.6	42 - 56

*Permanent pasture.

TABLE 6

Irrigation of Lettuce in Salinas Valley, as Indicated by a Canvass by the Soil Conservation Service, U.S.D.A., 1945

Area	Spring Crop					Summer Crop				
	Total Acreage	Applications		Water Delivered		Total Acreage	Applications		Water Delivered	
		Average Number	Range	Average Total	Range		Average Number	Range	Average Total	Range
				Inches	Inches				Inches	Inches
Pressure	408.5	1.8	1-2	13.7	2-17	387.5	3.0	2-4	23.3	5 -25
East Side	225.0	3.7	3-5	10.8	7 -15	115.0	3.0	3	18.0	18
Forebay	362.0	3.5	3-5	31.1	23-38	322.0*	4.0	3-6	37.4	26-64
Arroyo Seco	30.0	5.0	5	13.0	13	-	-	-	-	-
Upper Valley	None	-	-	-	-	None	-	-	-	-

*A third crop on 163 acres received 4 irrigations totaling 53 inches; a third crop on 19 acres received 2 irrigation totaling 27 inches. Two 30-acre fields bore a preceding crop of cabbage; a 30-acre field bore a preceding crop of beans or beets.

TABLE 7

Irrigation of Lettuce in Selected Fields, Salinas Valley, as Measured by the State Division of Water Resources, 1945.

Well Number	Acres	Inches Depth per Irrigation 1st	2nd	3rd	4th	5th	6th	7th	Total Depth, Inches
Pressure Area									
1-C-27	8	3.3	3.6	2.4	1.6	9.9	-	-	20.8
2-C-73	100	5.4	4.6	2.7	2.4	2.9	-	-	18.0
3-D-24	9	3.9	3.6	3.6	18.8*	2.8	12.0		44.7
3-D-80	20	3.0	17.6*	8.4	3.8	-	-	-	32.8
East Side Area									
4-D-10	51	1.7	1.1	9.1*	2.8	3.4	4.1	-	22.2

*Seed germination exclusively.

Notes on Table 7. Lettuce reported under 1-C-27, 3-D-24, 3-D-80, 4-D-10 was preceded by a fall-grown cover crop which was irrigated up in Sept. 1944 and plowed under in December. This was comparable to seed germination of lettuce. This lettuce was planted in December-January and seed-germinated by winter precipitation. Lettuce under 3-D-24 and 3-D-80 are indicative of the general practice. One-third of the lettuce under 2-D-73 received the treatment described above. Two-thirds followed a December planted crop which was not irrigated and which was not turned under until March; first-crop lettuce was planted in April and irrigated up. This is representative of good or better than good practice, as the irrigators were exceptionally efficient.

TABLE 8

Irrigation of Truck Crops in Salinas Valley, as Indicated by a Canvass by the Soil Conservation Service, U.S.D.A., 1945

Area	Spring Crop: Crop	Acres	Applications Number: Average	Applications Number: Range	Water Delivered Inches: Average	Water Delivered Inches: Range	Summer Crop: Crop	Acres	Applications Number: Average	Applications Number: Range	Water Delivered Inches: Average	Water Delivered Inches: Range
Pressure							Carrots*	9	4	4	13	13
							Celery *	22	6	6	12	12
	Potatoes	43	2	2	5	5						
	Potatoes	15	1	1	4	4	-	-	-	-	-	-
	Carrots	20	4	4	21	21	-	-	-	-	-	-
	Carrots	11	1	1	2	2	Carrots	11	3	3	17	17
	-	-	-	-	-	-	Cabbage	20	3	3	9	9
	-	-	-	-	-	-	Broccoli	25	2	2	4	4
	Broccoli	100	3	3-4	6-1/8	6-1/8	Cover	100	1	1	1-3/4	1-3/4
	Cabbage	25	4	4	19	19	-	-	-	-	-	-
	-	-	-	-	-	-	Onions	63	2	2	26	26
	Total	214	2.7	2-4	8	2 -21	Total	250	3	1-6	10.8	1-3/4-26
East Side	Radishes	50	2	2	7	7	-	-	-	-	-	-
	Onions	60	5	5	50	50	-	-	-	-	-	-
	Onions	20	5	5	51	51	-	-	-	-	-	-
	Onions	50	5	5	49	40	-	-	-	-	-	-
	Carrots	65	4	4	38	38	-	-	-	-	-	-
	Carrots	30	4	4	35	35	Carrots	30	4	4	32	32
	Cover	56.2	2	2	41	41	Tomatoes	56.2	8	8	63	63
	Cover	91.2	2	2	10	10	Tomatoes	91.2	7	7	22	22
	Cover	46.2	2	2	10	10	Tomatoes	46.2	7	7	32	32
	Total	418.6	3.6	2-5	32.8	10-51	Total	196.6	6	4-8	40.8	22-63

*Preceded by spring crop of lettuce.

TABLE 9

Irrigation of Truck Crops in Selected Fields in the Pressure Area, Salinas Valley, as Measured by the State Division of Water Resources, 1945.

Well Number	Acres	Inches Depth per Irrigation 1st	2nd	3rd	4th	5th	6th	7th	8th	Total Depth Inches
1-B-34	50	0.6	0.7	0.6	0.7	0.9	0.9	1.1	1.0	6.5
1-C-19	45	4.0	6.4	6.2	3.3	4.3	2.1	-	-	26.3
2-C-75	43	1.7	2.3	(winter seeded)						4.0

Notes on Table 9: About 90 per cent of this truck acreage under 1-B-34 was irrigated by sprinkler; 10 per cent irrigated direct from pump. Irrigations were frequent and light. An experienced irrigator was in charge. (Amounts reported may have been slightly underestimated owing to the small acreage irrigated direct from pump.)

About 20 per cent of the truck acreage under 1-C-19 is irrigated by sprinkler; 25 acres by ditch-furrow. Peas were put in under the sprinkler and lettuce under the furrows, both getting one irrigation. Carrots followed the lettuce in May, getting one more irrigation. The peas in the 20 acres under sprinkler were followed by June-planted cabbage; the cabbage land being pre-irrigated. Cabbage was not transplanted but was sown direct - in other words, field grown. In the cases of both 1-B-34, and 1-C-19, truck was preceded by September-sown cover crop which was plowed under in the fall.

The 43 acres under 2-C-75 was in spring broccoli, which was winter-planted, germinated by precipitation and harvested in May. The two irrigations noted were in April and May. The broccoli crop was followed by beets.

TABLE 10

Irrigation of Beans in Selected Fields, Salinas Valley,
as Measured by the State Division of Water Resources, 1945.

Well Number	Acres	Inches Depth per Irrigation 1st	2nd	3rd	Total Depth, Inches
Pressure Area					
3-D-24	14	5.0*	-	-	5.0
3-D-80	35	12.1	7.5	-	19.6
East Side Area					
4-D-10 and 4-D-12	140	7.7	5.6	6.7	20.0
4-D-16	200	4.2	2.8	2.6	9.6

* Seed germination exclusively.

Notes on Table 10: Beans under 3-D-24 were preceded by a September-sown cover crop. Beans were planted late in April, were not irrigated up, and crop was made with one irrigation. Beans under 3-D-80 were preceded by winter-seeded lettuce, which was matured without irrigation. This does not represent general practice, but is occasional. Beans under 4-D-10, 4-D-12, and 4-D-16 were preceded only by matured grasses, which were plowed under in late winter. Beams came up without irrigation. The three irrigations shown represent full requirements after summer fallowing.

TABLE 11

Irrigation of Beans in Salinas Valley,
as Indicated by a Canvass by the Soil Conservation Service, U.S.D.A., 1945.

Area	Beans					Winter Crop				
	Acres	Applications Number		Water Delivered Inches		Acres	Applications Number		Water Delivered Inches	
		Average	Range	Average	Range		Average	Range	Average	Range
East Side	135	4	4-5	18.5	17-19	-	-	-	-	-
Forebay	368	4	4	49.4	28-65	*	1	1	12	12
Arroyo Seco	332	3	2-4	34.0	13-52	**	1-2/3	1-2	10.8	10-14

*Onions, sugar-beets, lettuce and onions. Only lettuce was irrigated, 30 acres being given the one 12-inch application.

**Lettuce, spinach, and barley, totaling 71 acres.

TABLE 12

Irrigation of Sugar Beets in Salinas Valley,
as Indicated by a Canvass by the Soil Conservation Service, U.S.D.A., 1945.

Area	First Crop (sugar beets)					Second Crop (cover)				
	Acres	Applications Number		Water Delivered Inches		Acres	Applications Number		Water Delivered Inches	
		Average	Range	Average	Range		Average	Range	Average	Range
Pressure	195	2.5	2-3	10.6	3-36	-	-	-	-	-
Forebay	449.1	3.4	2-4	41.0	13-51	400	1	1	13	11-15

TABLE 13

Irrigation of Sugar Beets in Selected Fields, Salinas Valley, as Measured by the State Division of Water Resources, 1945.

Well Number	Acres	Inches Depth per Irrigation				Total Depth, Inches
		1st	2nd	3rd	4th	
			Pressure Area			
1-C-27	18.5	1.9	2.8	7.9**	-	12.6
2-C-75	43	10.2*	4.1	3.2	4.2	21.7
3-D-80	20	3.1	8.9	-	-	12.0
3-D-82	28	8.3	9.8	-	-	18.1
			East Side Area			
4-D-10) 4-D-12)	70	5.2	3.6	5.9	5.4	20.1

*Seed germination exclusively.
**High water table.

Notes on Table 13: Beets under 1-C-27 were preceded by a September-sown crop, which was irrigated up. Beets were sown in December. The crop under 2-C-75 was preceded by winter-planted spring broccoli, which was germinated by precipitation and harvested in May. The beets were given a germination irrigation about June 1 and three later irrigations for moisture replenishment. About 85 per cent of the beets in Salines Valley are winter-sown rather than irrigated up, but for the 15 per cent in the Pressure Area that are irrigated up, this represents average practice. The beets under 3-D-80, 3-D-82, 4-D-10 and 4-D-12 were December-sown. All were preceded by a September-sown cover crop which was plowed under in late fall. 3-D-80 and 3-D-82 received two irrigations, which are about representative of practice in the Pressure Area, while the four irrigations for 4-D-10 and 4-D-12 are good practice in the East Side Area.

TABLE 14

Irrigation of Artichokes in Selected Fields, Salinas Valley, as Measured by the State Division of Water Resources, 1945.

Well Number	Acres	Inches Depth per Irrigation					Total Depth, Inches
		1st	2nd	3rd	4th	5th	
1-B-3	75	5.0	1.4	1.5	1.3	0.9	10.1
1-B-4	77	6.1	1.9	1.4	2.1	1.5	13.0
1-B-8	65	4.7	4.3	3.9	2.1	2.9	17.9

TABLE 15

Quantity of Irrigation Water Applied to Guayule Plots in Lower Salinas Valley, 1943-44.*

Location	Acres	Average Length of Runs - Feet	Soil Type	Irrigation Dates	Irrigation Depth - Inches
Soledad Ranch, Soledad	10.82	484	Sandy loam	7- 2-43	6.5
				8-25-43	4.9
				Total	11.4
Clerk Ranch, Soledad	12.2	590	Loam and sandy loam	6- 6-43	4.85
				7- 9-43	6.46
				8-27-43	2.56
				Total	13.87
Jacks Ranch Chualar	10.7	405	Loam	7-19-43	5.93
				Total	5.93
Scattini Ranch, Greenfield	-	-	-	4-10-44	3.0
				5-17-44	5.9
				8- 3-44	4.1
				Total	13.0

*From data furnished by Emergency Rubber Project, U. S. Forest Service.

TABLE 16

Normal Monthly Temperature and Precipitation, Per Cent of Daytime Hours and Calculated Consumptive Use Factor, Salinas, California.

Month	Mean Temperature t	Daytime hours p	Consumptive use factor f	Normal Precipitation
	°F.	Per Cent		Inches
January	49.1	[illegible]	3.41	[illegible]
February	51.3	6.83	[illegible]	[illegible]
March	53.3	8.35	4.45	2.23
April	55.6	8.86	4.93	1.11
May	58.6	9.85	5.77	.46
June	60.7	9.87	5.99	.12
July	61.8	10.03	6.2[illegible]	.01
August	61.9	9.43	5.84	.02
September	62.0	8.37	5.19	.23
October	59.0	7.83	4.62	.56
November	54.2	6.89	3.73	1.20
December	50.4	6.74	3.40	2.47
Annual	56.5	100.00	57.03	1[illegible].90

t = Mean monthly temperature
p = Per cent of daytime hours of year for month
f = $\frac{t \times p}{100}$ = Monthly consumptive use factor

TABLE 17

Mean Monthly Temperatures, Precipitation, Per Cent of Daytime Hours and Calculated Consumptive Use Factor, Salinas, California, October 1, 1943 to September 30, 1945.

Month	Period: October 1, 1943 to September 30, 1944: Mean 1/ temperature t	Daytime hours 2/ p	Consumptive use factor f 3/	Precipitation 4/	Period: October 1, 1944 to September 30, 1945: Mean 1/ temperature t	Daytime hours 2/ p	Consumptive use factor f 3/	Precipitation 4/
	°F.	Per Cent		Inches	°F.	Per Cent		Inches
October	59.4	7.83	4.65	0.36	61.8	7.83	4.84	1.17
November	57.1	6.89	3.93	.24	53.9	6.89	3.71	3.78
December	50.6	6.74	3.41	2.49	53.2	6.74	3.59	1.81
January	50.2	6.95	3.49	2.51	50.6	6.95	3.52	.40
February	49.1	6.83	3.35	5.89	51.8	6.83	3.54	2.70
March	53.0	8.35	4.43	.19	51.6	8.35	4.31	2.72
April	51.9	8.86	4.60	1.31	53.1	8.86	4.70	.34
May	58.2	9.85	5.73	.52	57.2	9.85	5.63	.10
June	60.0	9.87	5.92	.15	61.2	9.27	6.04	T
July	61.2	10.03	6.14	.05	63.2	10.03	6.34	.0
August	60.8	9.43	5.73	T	61.4	9.43	5.79	.28
September	60.7	8.37	5.08	0	63.4	8.37	5.31	.05
Annual	56.00	100.00	56.46	13.71	56.9	100.00	57.32	13.35

1/ Average of Salinas and King City

2/ Latitude 36°20' N.

3/ f= $\frac{t \times p}{100}$ = Monthly consumptive use factor

4/ Calculated from 42-year ratio between Salinas and Soledad.

TABLE 18

Normal Montnly Temperetures and Precipitation, Per Cent of Daytime Hours and Calculated Consumptive Use Factor, Soledad, California

Month	Mean Temperature 1/ t	Daytime hours 2/ p	Consumptive Use Factor 3/ f	Normal Precipitation 4/
	°F.	Per Cent		Inches
January	48.7	6.97	3.39	2.[illegible]6
February	50.8	6.85	3.48	1.52
March	53.9	8.35	4.50	1.64
April	56.7	8.86	5.02	.64
May	60.6	9.83	5.96	.30
June	63.2	9.85	6.23	.04
July	65.1	10.01	6.52	T
August	64.9	9.41	6.11	.01
September	64.3	8.36	5.38	.11
October	60.6	7.84	4.75	.41
November	54.5	6.90	3.76	.96
December	49.9	6.77	3.38	1.43
Annual	57.8	100.00	58.48	9.12

1/ Average of Salinas and King City including 1944 record.
2/ p = Per cent of daytime hours of year for month; latitude 36°20' N.
3/ f = $\frac{t \times p}{100}$ = Monthly consumptive use factor.

4/ 72-year mean, calculated from ratio of 42-year average, Soledad record to Salinas record, by Simpson.

TABLE 19

Mean Monthly Temperatures, Precipitation, Per Cent of Daytime Hours and Calculated Consumptive Use Factor, Soledad, California, October 1, 1943 to September 30, 1945.

Month	Period: October 1, 1943 to September 30, 1944				Period: October 1, 1944 to September 30, 1945			
	Mean temperature t 1/	Daytime hours p 2/	Consumptive use factor f 3/	Precipitation 4/	Mean temperature t 1/	Daytime hours p 2/	Consumptive use factor f 3/	Precipitation 4/
	°F.	Per Cent		Inches	°F.	Per Cent		Inches
October	60.4	7.84	4.74	0.25	62.6	7.84	4.91	0.80
November	56.4	6.90	3.89	.18	53.3	6.90	3.68	2.87
December	50.5	6.77	3.42	1.62	52.4	6.77	3.55	1.18
January	50.1	6.97	3.49	1.73	49.7	6.97	3.46	.28
February	48.7	6.85	3.34	3.59	51.3	6.85	3.51	1.65
March	53.1	8.35	4.43	.13	50.8	8.35	4.24	1.88
April	52.9	9.86	4.69	.73	54.6	8.86	4.84	.19
May	59.3	9.83	5.83	.31	58.1	9.83	5.71	.06
June	61.4	9.85	6.05	.47	63.3	9.85	6.23	T
July	63.4	10.01	6.35	.05	65.9	10.01	6.60	.0
August	63.4	9.41	5.96	T	64.1	9.41	6.03	.14
September	63.5	8.36	5.31	.00	65.4	8.36	5.47	.03
Annual	56.9	100.00	57.50	9.06	57.6	100.00	58.23	9.08

1/ Average of Salinas and Kings City

2/ Latitude 36°20' N.

3/ $f = \frac{t \times p}{100}$ = Monthly consumptive use factor

4/ Calculated from 42-year ratio between Salinas and Soledad

TABLE 20

Normal Monthly Temperatures and Precipitation, Per Cent of Daytime Hours and Calculated Consumptive Use Factor, King City, California. 1/

Month	Mean Temperature t 1/	Daytime hours p 2/	Consumptive Use Factor f 3/	Normal Precipitation 4/
	°F.	Per Cent		Inches
January	48.2	6.98	3.36	2.43
February	50.4	6.86	3.46	2.12
March	54.6	8.35	4.56	1.93
April	57.9	8.85	5.12	.64
May	62.5	9.82	6.14	.26
June	65.7	9.84	6.46	.05
July	68.4	10.00	6.84	T
August	67.8	9.41	6.38	.01
September	66.6	8.36	5.57	.17
October	62.2	7.84	4.88	.38
November	54.8	6.91	3.79	.90
December	49.4	6.78	3.35	1.78
Annual	59.0	100.00	59.91	10.67

1/ Old station was closed May 31, 1944. New station is at the airport.

2/ p = Per cent of daytime hours of year for month; latitude 36°10' N.

3/ $f = \frac{t \times p}{100}$ = Monthly consumptive use factor.

TABLE 21

Mean Monthly Temperatures, Precipitation, Per Cent of Daytime Hours and Calculated Consumptive Use Factor, King City, California, October 1, 1943 to September 30, 1945.

Month	Period: October 1, 1943 to September 30, 1944				Period: October 1, 1944 to September 30, 1945			
	Mean temperature t	Daytime hours 1/ p	Consumptive use factor f 2/	Precipitation	Mean temperature t	Daytime hours 1/ p	Consumptive use factor f 2/	Precipitation
	°F.	Per Cent		Inches	°F.	Per Cent		Inches
October	61.4	7.84	4.81	0.22	63.4	7.84	4.97	0.06
November	55.7	6.91	3.85	.23	52.8	6.91	3.65	.95
December	50.4	6.78	3.42	2.02	51.6	6.78	3.50	1.36
January	50.0	6.98	3.49	2.02	48.8	6.98	3.41	.25
February	48.2	6.86	3.31	5.41	50.8	6.86	3.48	2.69
March	53.2	8.35	4.44	.22	49.9	8.35	4.17	1.44
April	53.9	8.85	4.77	.55	56.2	8.85	4.97	.12
May	60.5	9.82	5.94	.23	59.1	9.82	5.80	T
June	62.9	9.84	6.19	.02	65.4	9.84	6.44	.02
July	65.6	10.00	6.56	T	68.6	10.00	6.86	0
August	65.9	9.41	6.20	T	66.8	9.41	6.29	.03
September	66.3	8.36	5.54	.01	67.3	8.36	5.63	.05
Annual	57.8	100.00	58.52	10.93	58.4	100.00	59.17	6.97

1/ p = Per cent of daytime hours of year for month; latitude 36°10' N.

2/ $f = \frac{t \times p}{100}$ = Monthly consumptive use factor.

TABLE 22

Observed Monthly Evaporation from U. S. Weather Bureau Pan and Mean Temperature, Computed Coefficients, Newark, California

Month	1942		1943		1944		Average		Per Cent daytime hours (p)	Consumptive Use factor (f)	Coefficient 1/ (k)
	Evaporation	Temperature	Evaporation	Temperature	Evaporation	Temperature	Evaporation	Temperature			
	Inches	°F.	Inches	°F.	Inches	°F.	Inches	°F.			
January	1.27	50.5	1.44	47.8	1.29	48.0	1.33	48.8	6.90	3.37	0.395
February	2.28	51.0	1.88	52.2	2.24	48.4	2.13	50.5	6.81	3.44	.619
March	3.91	53.1	2.62	54.2	4.34	52.4	3.62	53.2	8.34	4.44	.815
April	4.10	54.2	4.44	56.0	4.75	52.7	4.43	54.3	8.38	4.82	.919
May	6.82	57.2	8.35	61.2	7.65	59.7	7.61	59.4	9.99	5.88	1.294
June	9.00	61.4	8.22	62.0	7.08	61.5	8.10	61.6	9.92	6.11	1.325
July	9.33	64.6	8.77	65.1	8.38	63.6	8.83	64.4	10.07	6.49	1.360
August	7.78	64.3	8.05	64.8	7.85	63.4	7.89	64.2	9.46	6.07	1.300
September	5.88	62.2	6.76	66.0	6.24	64.6	6.29	64.3	8.38	5.39	1.167
October	4.22	59.8	4.43	60.4	3.81	60.4	4.15	60.2	7.81	4.70	.883
November	2.07	52.2	2.16	54.7	2.23	51.6	2.15	52.8	6.84	3.61	.600
December	1.09	48.1	1.85	49.8	0.80	49.4	1.25	49.1	6.69	3.28	.381
Annual	57.75	56.6	58.97	57.8	56.66	56.3	57.78	56.9	100.00	57.60	---

t = Mean monthly temperatura
p = Per cent of daytime hours of year for month

$f = \frac{t \times p}{100}$ = Monthly consumptive use factor

$k = \text{coefficient} = \frac{\text{Evaporation}}{\text{Consumptive use factor}}$

TABLE 23

Estimated Normal Eveporation at Salinas (Pressure and East Side Areas) and Soledad (Forebay and Arroyo Seco Areas), Salinas Valley, California.

Month	Coefficient 1/ (k)	Consumptive use factor (f)		Evaporation at Salinas			Evaporation at Soledad		
		Salinas	Soledad	Pan 2/	Lake 3/		Pan 2/	Lake 3/	
				Inches	Inches	Ft.	Inches	Inches	Ft.
November	0.600	3.75	3.76	2.24	1.72	0.143	2.26	1.74	0.15
December	.381	3.40	3.38	1.30	1.00	.083	1.29	.99	.08
January	.395	3.41	3.39	1.35	1.04	.087	1.34	1.03	.08
February	.619	3.50	3.48	2.17	1.67	.139	2.15	1.66	.14
March	.815	4.45	4.50	3.63	2.80	.233	3.67	2.83	.24
Sub-total				10.69	8.23	.685	10.71	8.25	.69
April	.919	4.93	5.02	4.53	3.49	.291	4.61	3.55	.30
May	1.294	5.77	5.96	7.47	5.75	.479	7.71	5.94	.49
June	1.325	5.99	6.23	7.94	6.11	.509	8.25	6.35	.53
July	1.360	6.20	6.52	8.43	6.49	.541	8.87	6.83	.57
August	1.300	5.84	6.11	7.59	5.84	.487	7.94	6.11	.51
September	1.167	5.19	5.38	6.06	4.67	.389	6.28	4.84	.40
October	.883	4.62	4.75	4.08	3.14	.262	4.19	3.23	.27
Sub-totel				46.10	35.49	2.958	47.85	36.85	3.07
Annual		57.03	58.48	56.79	43.72	3.643	58.56	45.10	3.76

1/ k = coefficient developed from observed date at Newark, Calif. (See Table 22.)
2/ Computed evaporation = k x f.
3/ Lake surface = pan eveporation x 0.77.

TABLE 24

Observed Monthly Maen Temperaturas, and Consumptive usa of Water by Tules Growing in a Tank Located in Swamp, San Luis Rey Valley, California, and Computed Coefficients.

Month	1940		1941		1943		Averege		Per Cent daytime hours (p)	Consumptive Use factor (f)	Coefficient 1/ (k)
	Evaporation	Temperature	Evaporation	Tamperature	Evaporation	Tamperature	Evaporation	Tamperature			
	Inches	°F.	Inches	°F.	Inches	°F.	Inches	°F.			
January	0.91	55.8	2.01	53.4	2.55	55.5	1.82	54.9	7.13	3.91	0.47
February	1.77	55.8	1.63	56.0	2.29	53.3	1.90	55.0	6.93	3.81	.50
March	3.31	58.8	3.65	57.6	2.30	55.4	3.09	57.3	8.36	4.79	.65
April	5.30	62.3	4.62	54.8	3.76	57.4	4.56	58.2	8.79	5.12	.89
May	7.57	66.7	7.63	64.3	6.00	61.6	7.07	64.2	9.69	6.22	1.14
June	7.23	68.0	7.46	65.4	7.69	66.7	7.46	66.7	9.66	6.44	1.16
July	9.00	69.5	8.19	69.9	8.92	70.6	8.70	70.0	9.84	6.89	1.26
August	7.60	74.9	7.10	69.8	8.59	70.3	7.76	71.7	9.32	6.68	1.16
September	6.12	67.2	5.89	64.8	7.21	66.2	6.41	66.1	8.34	5.51	1.16
October	5.94	64.2	4.22	61.7	5.06	64.9	5.07	63.6	7.91	5.03	1.01
November	3.02	57.6	2.47	56.0	4.04	57.6	3.18	57.1	7.04	4.02	.79
December	2.04	56.1	2.21	51.0	1.52	53.7	1.92	53.6	6.97	3.74	.51
Annual	59.81	63.1	57.08	60.4	59.93	61.1	58.94	61.5	100.00	62.16	--

1/ $k = \text{Coefficient} = \frac{\text{Consumptive Use}}{\text{Consumptive Use Factor}}$

TABLE 25

Estimated Normal Consumptive Use of Water by Swamp Areas at Salinas (Pressure and East Side Areas) and at Soledad (Forebay and Arroyo Seco Areas), Salinas Valley, California.

Month	Coefficient (Swamp)	Consumptive Use, Salinas		Consumptive Use, Soledad	
	(k) 1/	(u) 2/	(u) 2/	(u) 3/	(u) 3/
		Inches	Feet	Inches	Feet
November	0.79	2.95	0.246	2.97	0.248
December	.51	1.73	.144	1.72	.143
January	.47	1.60	.133	1.59	.133
February	.50	1.75	.146	1.74	.145
March	.65	2.89	.241	2.93	.244
Sub-total	2.92	10.92	.910	10.95	.913
April	.89	4.39	.366	4.47	.373
May	1.14	6.58	.548	6.79	.566
June	1.16	6.95	.579	7.23	.603
July	1.26	7.81	.651	8.22	.685
August	1.16	6.77	.564	7.09	.591
September	1.16	6.02	.502	6.24	.520
October	1.01	4.67	.389	4.80	.400
Sub-total	7.78	43.19	3.599	44.84	3.738
Annual	10.70	54.11	4.509	55.79	4.651

1/ k = Coefficient developed from observed data in San Luis Rey Valley. (See Table 24).
2/ u = Monthly consumptive use = k x consumptive use factor at Salinas.
3/ u = k x consumptive use factor at Soledad.

TABLE 26

Observed Consumptive Use of Water by Intermingled Dense Growth of Trees and Grasses in a Tank With the Water at 4 Feet Below the Ground Surface in San Luis Rey Valley, California, and Computed Normal Consumptive Use at Salinas, California.

Month or Period	San Luis Rey (12)					Salinas (Normal)	
	Observed Consumptive Use			Consumptive use factor 2/	Coefficient 3/	Consumptive use factor	Consumptive use 4/
	1941-42	1942-43	Ave. 1/	(f)	(K)	(f)	
	Inches	Inches	Inches				Inches
October			3.65	5.01	0.73	4.62	3.37
November			2.00	4.01	.50	3.73	1.86
December			1.24	3.66	.34	3.40	1.15
January			1.53	3.91	.39	3.41	1.33
February			1.89	3.80	.50	3.50	1.75
March			3.21	4.72	.68	4.45	3.02
Sub-total	12.73	14.32	13.52	25.11	0.54	23.11	12.48
April	5.15	5.82	5.49	4.93	1.11	4.93	5.47
May	8.52	6.65	7.58	6.10	1.24	5.77	7.15
June	7.49	8.69	8.09	6.36	1.27	5.99	7.61
July	9.55	10.98	10.27	6.90	1.49	6.20	9.24
August	9.37	9.93	9.65	6.52	1.48	5.84	8.64
September	7.16	8.66	7.91	5.46	1.45	5.19	7.52
Sub-total	47.24	50.73	48.99	36.27	1.35	33.92	45.63
Year	59.97	65.05	62.51	61.38	-	57.03	58.11

1/ Monthly distribution of six-month period, October 1 to April 1, estimated from monthly Weather Bureau evaporation pan record.
2/ f = Temperature (t) x per cent of daytime hours (p) = consumptive use factor.
3/ k = Observed consumptive use, San Luis Rey / Consumptive use factor, San Luis Rey = Coefficient.
4/ Computed consumptive use k x f (Salinas).

TABLE

Computed Normal Monthly Consumptive Use of Water by Dense Growth of Native Vegetation (Trees-Brush-Grass) at Salinas, Pressure and East Side Areas and Soledad (Forebay and Arroyo Seco Areas), Salinas Valley, California.

Month	Coefficient 1/ (k)	Consumptive Use, Salinas		Consumptive Use, Soledad	
		(k) 2/	(u)	(k) 3/	(u)
		Inches	Feet	Inches	Feet
November	[illegible]	[illegible]	.115	[illegible]	.157
December	.34	1.15	[illegible]	1.15	[illegible]
January	.79	[illegible]	.111	1.32	.110
February	.50	1.75	.146	1.74	.145
March	.68	[illegible]	.252	[illegible]	.255
Sub-total	2.41	9.11	.760	9.15	.763
April	1.11	[illegible]	.456	5.57	.464
May	1.24	.15	.596	[illegible]	.616
June	1.27	[illegible]	.634	[illegible]	.658
July	1.49	[illegible]	[illegible]	[illegible]	[illegible]
August	1.45	[illegible]	[illegible]	[illegible]	.753
September	1.45	7.52	.627	7.80	.650
October	.73	3.37	.281	3.47	.288
Sub-Total	[illegible]	[illegible]	4.[illegible]84	50.89	4.237
Annual	11.18	5[illegible].11	4.844	60.04	5.00

1/ k = Coefficient developed from observed data in San Luis Rey Valley.
2/ u = Monthly consumptive use = coefficient (k) x consumptive use factor (f) at Salinas.
3/ u = Monthly consumptive use = coefficient (k) x consumptive use factor (f) at Soledad.

TABLE 28

Estimated Normal Annual Consumptive Use of Water by Trees-Brush-Grass, Pressure, East Side, Forebay, Arroyo Seco, and Upper Valley Areas in Salinas Valley, California.

Types of Vegetation	Depth to Water-table		Consumptive Use						
	Range	Average	San Luis Rey	Pressure and East Side Areas		Forebay and Arroyo Seco Areas		Upper Valley Area	
	Feet	Feet	Inches	Inches	Feet	Inches	Feet	Inches	Feet
Dense: Trees-brush-grass	3 to 5	4.0	62.5	58.1	4.84	60.0	5.00	62.0	5.17
Medium: Brush-trees-grass	4 to 7	5.5	36.0	33.5	2.79	34.2	2.85	34.2	2.93
Sparse: Brush-grass	6 to 10	8.0	21.0	19.5	1.63	20.0	1.67	20.5	1.71

TABLE 29

Computed Normal Unit Consumptive Use of Water by Alfalfa, Salinas Valley, California.

Month	Pressure and East Side Areas				Forebay and Arroyo Seco Areas				Upper Valley Area			
	Consumptive use factor (f)	Coefficient (k)	Consumptive use (u) Inches	Consumptive use (u) Feet	Consumptive use factor (f)	Coefficient (k)	Consumptive use (u) Inches	Consumptive use (u) Feet	Consumptive use factor (f)	Coefficient (k)	Consumptive use (u) Inches	Consumptive use (u) Feet
November	3.73	0.6	2.34	0.19	3.76)				3.79	0.6	2.27	0.19
December	3.40	.4	1.36	.11	3.38)				3.35	.4	1.34	.11
January	3.41	.4	1.36	.11	3.39)		Rainfall only		3.36	.4	1.34	.11
February	3.50	.5	1.75	.15	3.48)				3.46	.5	1.73	.15
March	4.45	.5	2.22	.18	4.50)				4.56	.5	2.28	.19
Total for period			8.93	.74			7.61	0.63			8.96	.75
April	4.93	0.6	2.96	0.25	5.02	0.6	3.01	0.25	5.12	0.6	3.07	0.26
May	5.77	.7	4.04	.34	5.96	.7	4.17	.35	6.14	.7	4.30	.36
June	5.99	.8	4.79	.40	6.23	.8	4.98	.42	6.46	.8	5.17	.43
July	6.20	.8	4.96	.41	6.52	.85	5.54	.46	6.84	.85	5.81	.48
August	5.84	.8	4.67	.39	6.11	.85	5.19	.43	6.38	.85	5.42	.45
September	5.19	.8	4.15	.34	5.38	.85	4.57	.38	5.57	.85	4.73	.39
October	4.62	.7	3.23	.27	4.75	.70	3.33	.28	4.88	.70	3.42	.29
Total for period			28.80	2.40			30.79	2.57			31.92	2.66
Annual			37.73	3.14			38.40	3.20			40.88	3.41

TABLE 30

Estimated Normal Unit Consumptive Use of Water in Feet for Agricultural Crops in Pressure Area, Salinas Valley, California

Crop			Consumptive Use of Water							
			Winter Nov. 1 to Mar. 31		Summer 1/ Apr. 1 to Oct. 31		Annual		Summer 1/ 1944	1945
			Inches	Feet	Inches	Feet	Inches	Feet	Inches	Feet
Alfalfa	(a)		8.9	0.74	28.8	2.40	37.7	3.14	2.37	2.41
Alfalfa 2/	(a)		8.9	.74	23.0 2/	1.92	31.9	2.66	1.90	1.93
Lettuce	(l)	(2/3)	8.0	.67	11.0	.91	19.0	1.58	.90	.91
Lettuce	(l)	(1/3)	10.0	.83	6.8	.57	16.8	1.40	.56	.57
Truck	(t)	(3/4)	8.0	.67	18.0	1.50	26.0	2.17	1.48	1.50
Truck	(t)	(1/4)	10.0	.83	12.0	1.00	22.0	1.83	.99	1.00
Beans	(b)	(81%)	8.0	.67	9.0	.75	17.0	1.42	.74	.75
Beans	(b)	(19%)	7.0	.58	12.0	1.00	19.0	1.58	.99	1.00
Sugar Beets	(sb)	(85%)	10.0	.83	11.0	.92	21.0	1.75	.91	.92
Sugar Beets	(sb)	(15%)	8.0	.67	13.6	1.13	21.6	1.80	1.12	1.13
Artichoke	(A)		4.0	.33	14.5	1.21	18.5	1.54	1.19	1.21
Guayule	(g)		10.0	.83	10.0	.83	20.0	1.66	.82	.83
Seeds	(M)		8.0	.67	12.5	1.04	20.5	1.71	1.03	1.04
Orchards	(o)		8.0	.67	16.0	1.33	24.0	2.00	1.31	1.33
Grain	(g1)		8.0	.67	8.6	.72	16.6	1.39	.71	.72

1/ Irrigation season. 2/ Twenty per cent (20%) deducted for summer pasture.

TABLE 37

Estimated Normal Unit Consumptive Use of Water For
Agricultural Crops in Forebay Area, Salinas Valley, California

Crop		Consumptive Use of Water					
		Winter: Nov. 1 to Mar. 31		Summer 1/: Apr. 1 to Oct. 31		Annual	
		Inches	Feet	Inches	Feet	Inches	Feet
Alfalfa	(a)	7.6	0.63	36.8	3.07	44.4	3.70
Lettuce	(l)	7.6	.63	12.4	1.03	20.0	1.66
Truck	(t)	7.6	.63	16.6	1.38	24.2	2.01
Beans	(b)	7.6	.63	13.8	1.14	21.4	1.77
Beets	(sb)	10.0	.83	14.0	1.17	24.0	2.00
Guayule	(g)	7.6	.63	13.8	1.15	21.4	1.78
Orchard	(o)	7.6	.63	15.4	1.28	23.0	1.91
Grain	(gi)	7.6	.63	9.5	.71	17.1	1.34

1/ Irrigation season.

TABLE 38

Estimated Normal Unit Consumptive Use of Water For
Agricultural Crops in Arroyo Seco Area, Salinas Valley, California

Crop		Consumptive Use of Water					
		Winter: Nov. 1 to Mar. 31		Summer 1/: Apr. 1 to Oct. 31		Annual	
		Inches	Feet	Inches	Feet	Inches	Feet
Alfalfa	(a)	7.6	0.63	36.8	3.07	44.4	3.70
Lettuce	(l)	7.6	.63	12.4	1.03	20.0	1.66
Truck	(t)	7.6	.63	16.6	1.38	24.2	2.01
Beans	(b) (75%)	7.6	.63	14.2	1.18	21.8	1.81
Beans	(b) (25%)	7.6	.63	13.4	1.12	21.0	1.75
Sugar Beets	(sb)	10.0	.83	14.0	1.17	24.0	2.00
Guayule	(g)	7.6	.63	13.8	1.15	21.4	1.78
Seeds	(s)	7.6	.63	13.8	1.15	21.4	1.78
Orchard	(o)	7.6	.63	15.4	1.28	23.0	1.91
Grain	(gi)	7.6	.63	9.5	.71	17.1	1.34

1/ Irrigation season.

TABLE 34

Estimated Normal Unit Consumptive Use of Water for Agricultural Crops in Upper Valley Area, Salinas Valley, California.

Crop		Consumptive Use of Water					
		Winter Nov. 1 to Mar. 31		Summer 1/ Apr. 1 to Oct. 31		Annual	
		Inches	Feet	Inches	Feet	Inches	Feet
Alfalfa	(a)	[illegible]	0.75	1.[illegible]	2.66	4[illegible].9	3.41
Truck	(t)	[illegible]	.75	1[illegible]	1.50	27.0	2.25
Beans	(b) (75%)	9.[illegible]	.75	1[illegible]	1.25	24.0	2.00
Beans	(b) (25%)	[illegible]	.75	14.[illegible]	1.17	23.[illegible]	1.92
Sugar Beets	(sb)	1[illegible]	.83	14.[illegible]	1.17	24.[illegible]	2.00
Guayule	(g)	[illegible]	.75	13.[illegible]	1.13	22.5	1.[illegible]
Seeds	(M)	[illegible]	.75	1[illegible]	1.[illegible]	2[illegible]	1.34
Orchard	(o)	[illegible]	.[illegible]5	1[illegible]	1.[illegible]	2[illegible]	2.[illegible]9
Grain	(gi)	[illegible]	.[illegible]	[illegible].5	.71	17.5	1.4[illegible]

1/ Irrigation season.

TABLE 35

Summary of Estimated Normal Unit Consumptive Use of Water for Other Classification in Salinas Valley, California.

	Consumptive Use in Feet 1/								
	Pressure and East Side Areas			Forebay and Arroyo Seco Areas			Upper Valley Area		
	Winter 2/	Summer 3/	Annual	Winter 2/	Summer 3/	Annual	Winter 2/	Summer 3/	Annual
Irrigable dry farm and grass	[illegible].50	0.60	1.1[illegible]	[illegible].4[illegible]	.35	[illegible].75	.5[illegible]	0.33	[illegible].33
River channel 4/	.46	1.28	1.74	.46	1.32	1.78	.46	1.35	1.81
Wasteland 5/	.33	.17	.[illegible]	.25	.15	.40	.33	.12	.45
Town and farm lots	.50	1.5[illegible]	2.[illegible]	.50	1.5[illegible]	[illegible]	.50	1.50	2.[illegible]
Roads and railroads	.30	.[illegible]	.[illegible]	.25	.15	.40	.30	.12	.42

1/ Acre-feet per acre.
2/ November 1 to March 31.
3/ April 1 to October 31.
4/ Free water surface, January 1 to [illegible].
5/ Evaporation after rainfall.

TABLE [illegible]

Coefficients for Reducing Normal Consumptive Use to Consumptive Use for 1944 and 1945 Summer and Water Year Periods in Salinas Valley, California.

Area	Percentages of Normal			
	Summer Period 1/		Water Year	
	1944	1945	1943-44	1944-45
Pressure East Side	92.7	10[illegible].3	[illegible]	100.5
Forebay Arroyo Seco	9[illegible]	9[illegible]	[illegible]	[illegible].6
Upper Valley	[illegible].1	[illegible]	[illegible]	[illegible]

1/ Irrigation season, April 1 to October 31.

APPENDIX B

AGREEMENT BETWEEN THE DEPARTMENT OF PUBLIC WORKS AND THE COUNTY OF MONTEREY FOR INVESTIGATION OF AND REPORT UPON WATER RESOURCES

AGREEMENT BETWEEN THE DEPARTMENT OF
PUBLIC WORKS AND THE COUNTY OF MONTEREY
FOR INVESTIGATION OF AND REPORT UPON
WATER RESOURCES

THIS AGREEMENT, executed in triplicate, entered into by and between the Department of Public Works of the State of California, acting by and through the State Engineer, hereinafter referred to as "Department" and the County of Monterey hereinafter referred to as "County".

W I T N E S S E T H:

WHEREAS, salt water intrusion into wells in the lower Salinas Valley, Monterey County, hes reached such proportions that it constitutes a menace to agricultural lands, and

WHEREAS, the County desires an investigation of the problems involved and a report thereon for the purpose of ascertaining causes and determining a solution, and

WHEREAS, the State has a paramount interest in the use of water and in the protection of the public interest in the development of water resources and the Department, acting by and through the State Engineer, is authorized in the Water Code to cooperate with any county in investigations of any water supply.

NOW THEREFORE, in consideration of the premises and the mutual agreements hereinafter contained, it is hereby agreed as follows:

(1) There shall be maintained in cooperation an investigation of the water resources of the Salinas Valley in Monterey County, California, and conditions relative thereto which obtain in said valley or affect the water supplies available therefor.

(2) The Department shall prepare a report based on said investigation setting forth the physical facts pertinent to water supply and to salt water intrusion and, if possible, incorporating findings as to a method or methods of solving the problems involved.

(3) The Department shall have sole direction, charge and control of said investigation and report, of its employees engaged therein, of the expenditure of all money provided herein for said work, and of all other matters appertaining thereto, and shall prepare and submit to the County a report containing the data gathered under the provisions of this agreement and such other relevant data as may be in the possession of the Department or readily available to it.

(4) This agreement may be terminated by either party upon thirty (30) days written notice to the other. If so terminated by the County then the Department shall be obligated to prepare and present only such report as is practicable with the funds which remain available and if terminated by the Department then the County shall be entitled to a full and complete report on all data and information gathered under the provisions of this agreement.

(5) The Department shall be the sole judge as to the scope of the investigation necessary to determine the various factors involved, as to the sufficiency of the investigation to satisfy the terms and provisions of this agreement, and as to the sufficiency of the report to be submitted by it hereunder.

(6) The County upon execution by it of this agreement shall forward to the Department, for expenditure by it in the performance of said work, the sum of Six Thousand Dollars ($6,000) which shall be deposited in a trust account in the Special Deposit Fund in the State Treasury and thereafter transferred to the Water Resources Fund.

(7) If the Director of Finance within thirty (30) days after receipt by the Department of said sum from the County shall not have allocated from the Emergency Fund (Stats. 1943, Chap. 62, Item 221) the sum of Six Thousand Dollars ($6,000) to the Department for expenditure in the performance of said work said sum so transmitted by the County shall be returned upon demand by the County if such demand is made after the expiration of said thirty (30) days and prior to the making of said allocation.

(8) Upon completion of and final payment for the work provided for in this agreement the Department shall furnish to the County a statement of all the expenditures made under this agreement and of any expenditures made on account of said work from State funds, if any, other than those allocated for said work from said emergency fund. One-half of the total amount of all said expenditures shall be deducted from the sum of Six Thousand Dollars ($6,000) advanced by the County for said work and any balance of said sum which may remain shall be returned to the County.

(9) It is understood by and between the parties hereto that the sum of Twelve Thousand ($12,000) to be made available as hereinabove provided may be insufficient to complete the investigation and report provided for herein and that, if such is found to be the case, it is the present intention of the County to make further sums available from time to time which will be subject to a matching or contribution in equal sums by the State for the completion of said investigation and report and it is also understood that it may be three years or more before said work can be completed

(10) The Department shall under no circumstances be obligated to expend for or on account of work provided for under this agreement any sum in excess of the total amount of money now or hereafter made available for said work, and in the event of inadequacy of funds shall be obligated to make only such an investigation and report as funds available therefor shall permit.

(11) This agreement shall become effective immediately after its execution by both parties hereto.

IN WITNESS WHEREOF, the parties hereunto have affixed their signatures and official seals, the County on the 10th day of July, 1944, and the Department on the 24th day of July, 1944.

Approved:

Approved:

Frank B. Durkee
Attorney,
Department of Public Works

Approved:

C. H. Purcell
Director of Public Works

Approved:

Jas. S. Dean
Director of Finance

Approved:

Anthony Brazil
by Chas. P. McHarry, Deputy
District Attorney of the
County of Monterey

Approved:

Spencer Burroughs
Principal Attorney for
Division of Water Resources

COUNTY OF MONTEREY

By A. B. Jacobsen
Chairman, Board of Supervisors

DEPARTMENT OF PUBLIC WORKS
State of California

By Edward Hyatt
State Engineer

APPENDIX C

IRRIGATION PRACTICES AND CONSUMPTIVE USE OF WATER IN SALINAS BASIN

By

Paul A. Ewing, Senior Irrigation Economist
Harry F. Blaney, Senior Irrigation Engineer

Division of Irrigation
Soil Conservation Service
United Stated Department of Agriculture

IRRIGATION PRACTICES *

This appendix is a contribution to a cooperative investigation initiated by the County of Monterey and the Division of Water Resources, Department of Public Works, State of California, involving the whole subject of the utilization of the water supply of the Salinas Valley in that county. Begun originally to ascertain the facts regarding the reported intrusion of saline waters into the underground supplies of areas farthest north in the valley, the investigation had been broadened to include ascertainment of the actual water requirements of the whole valley area, both present and prospective. Because of experience accumulated by the Division of Irrigation, Soil Conservation Service, along similar lines in other regions of the West, the Division of Water Resources invited entry of the Division of Irrigation into the Salinas Basin Investigation. The necessary studies were incorporated into the program for cooperative investigations authorized by a formal agreement already in effect between these Federal and State Divisions.

The methods principally involved in the irrigation of the crops reported in the 1944 crops survey by the State Division of Water Resources are discussed severally in this chapter. The 1944 acreage of these crops is previously set out in the final section of Teble 4 in Appendix A. Table 4 also includes the acreages in native vegetation classification and other water consuming areas. Consumptive uses of all vegetation listed in Table 4 are hereafter set forth in the contribution by Mr. Herry F. Blaney.

Alfalfa and Clover

Alfalfa, once dominant with sugar beets in the irrigation agriculture of Salinas Valley, has lost that position, although it is still an important crop. In the Pressure Area the alfalfa indicated in the crop survey is largely pasture, but elsewhere in the surveyed areas it is raised mainly for hay.

Ladino clover is relatively new in Salinas Valley, but the acreage devoted to it appears to be expanding rapidly. It is strictly an irrigated crop, requiring frequent applications of water throughout the growing seasor for maximum production. The frequency of irrigation varies with the soil type and its retentiveness of moisture, but the plant is shallow-rooted and unless the surface 18 inches or 2 feet of soil containing most of the roots is kept well supplied with water, maximum yields will not be obtained. Under average conditions elsewhere, an application of water every 10 to 16 days is considered necessary, but longer periods are permissible where soil conditions are exceptionally favorable and in areas of mild climate conditions such as those characterizing lower Salinas Valley.

While this clover requires frequent irrigation its total water requirements probably do not exceed those of alfalfa. Applications need only be light, perhaps not more than one or two inches each. All that is necessary is that the soil moisture be replenished to the depth of roots.

* By Peul A. Ewing, Senior Irrigation Economist, Division of Irrigation, Soil Conservation Service, United States Department of Agriculture.

Two of the ladino fields listed under the Pressure Area in Table 5, previously set forth in Appendix A, were irrigated by flooding directed through surface pipes operating on underground concrete pipe systems; the other was irrigated by the sprinkling method. The alfalfa field was irrigated by the usual border method, but also with apparent economy of water. These crops, especially in the Pressure Area, benefit from their access to the water table, which has much to do with the relatively light irrigations they received.

The permanent pasture field in the Forebay Area was also given an economical total amount of water, although irrigations were fairly frequent. In the Arroyo Seco Area the applications total substantially higher, averaging nearly twice as much as in the Pressure Area. The border method is practiced principally in this area.

Only one field of alfalfa was included in the study by the Division of Water Resources, this being a 10-acre field in the East Side Area that received four irrigations totaling 9.4 inches. This was a pasture. It received no winter irrigations (after November 1), and the irrigations were lighter than would have been the case had hay been harvested.

While both alfalfa and ladino, being perennials, are mostly raised independently of other cropping, alfalfa enters into rotations to some extent, especially in the Forebay and Arroyo Seco areas, because of its beneficial effects on soils adapted to sugar beets and beans.

On the basis of the data reported in Table 5, supplemented by the results of the study of the Division of Water Resources and general observations, the conclusion is thst alfalfa and ladino clover are given about the following total depths of water yearly: Pressure Area, 24 inches; East Side Area, 36 inches; Forebay and Arroyo Seco and Upper Valley areas, 42 inches.

Lettuce

While beans occupy the largest acreage of any of the agricultural crops reported in the 1944 cultural survey (see Table 4 in Appendix A), lettuce is a close second, and in the Pressure Area the net acreage taken up by this crop is by far the largest of all those listed. Since the water problem is acute in the Pressure Area the predominance of lettuce is of extra importance there because of the irrigation practices involved in its production. Specifically, these include substantial and repeated applications of water and, in many cases, the growing of two or even three crops on the same land in a single year--if not two crops of lettuce, then a crop of lettuce followed or preceded by a truck crop which often is also irrigated liberally. A fall or winter cover crop, notably vetch, sometimes is irrigated but usually grows under the stimulus of precipitation alone.

Salinas Valley soils adapted to the growing of lettuce range from sandy loams to clay loams which are fertile but sometimes not well drained. The best lettuce area is that in which fog is present for at least a few hours most days. Fogs have the effect of reducing plant transpiration and evaporation from the soil surface. The area now in lettuce includes a considerable acreage that previously had been in sugar beets. The low area between Salinas and Castroville was the site of the first extensive plantings, and lettuce still is prominent in that locality. The original concentration has been expanded, however, to include some areas of lighter soils at higher elevations, a number of these fields which formerly produced dry-farmed beans, barley and other field crops having been found adapted to the raising of early

lettuce despite water costs somewhat greater than those typical of the lower area. Fields in the lower area are relatively flat, slopes being around 1 per cent or less, but at the sides of the valley they are likely to be slightly steeper.

Notwithstanding the expansion of the lettuce area beyond that originally devoted to it, climatic and soil requirements tend to limit the ultimate lettuce acreage. County Agent A. A. Tavernetti some years ago estimated this maximum at 40,000 acres. Nevertheless, attainment of such a maximum would represent a 60 per cent increase (15,000 acres) of the present net lettuce acreage.

Unpublished reports of experiments on lettuce irrigation requirements, conducted in Salinas Valley by College of Agriculture of the University of California, note that while the measurements of water applied to commercial lettuce fields are not extensive, the experimenters believe that 6.1 inches is usually applied to germinate the seed.* It is noted also, however, that

> "Much greater applications have been measured--in one case as much as 26 inches was applied, the runs being excessively long and the soil highly permeable. Usually applications subsequent to thinning were from 2 to 4 inches. Much water is obviously wasted by deep percolation. Flooding experiments indicated that leaching of nitrates was probably a detrimental effect.
>
> "Excessive amounts of water to germinate seed in most instances is due to use of high beds--those 6 inches or more. High beds are necessary on land not properly leveled, as water must be kept in furrows until soil around the seed is moistened and the greater the distance the longer the time required to wet the soil. In a few tests where low beds were used, about one-half as much water was used in flooding as for the high beds. A bed need not be any higher than necessary to compensate for uneveness of the land and prevent the beds from being flooded. While lettuce can be raised by flooding the entire surface, crusting of the soil surface may interfere with seed emergence and leaching may occur.
>
> "Commercial plantings in Salinas Valley are made on raised beds in which two rows of lettuce are grown. Beds are commonly about 6 to 8 inches high and spaced 42 inches apart from center to center, the rows on each bed being 14 inches apart. Irrigation is accomplished by running water down each furrow between the beds. A small stream running many hours is the general practice. When water is applied to germinate the seed it is held in the furrow until it soaks into the beds. Irrigation runs may vary from a few hundred feet to more than 1000 feet, depending on slope, soil type, and individual preferences. In general, irrigations are more frequent on light sandy soils than on heavy soils, and the sandy soils are given more water than the heavier soils. As many as 6 to 8 irrigations have been made on one crop. In other cases, as few as 2 or 3 irrigations have been made on crops not receiving moisture from rainfall. A fairly common practice is to irrigate a crop lightly after a first cutting has been made and when two or three more cuttings are anticipated.
>
> "Usual tillage practices previous to planting are plowing, disking, and listing. Sled-type implements with planters attached are then used to shape the beds. Cultivation often begins shortly after the plants have two true leaves. A more common practice is to make the first cultivation shortly before the plants are thinned. The first cultivation is generally shallow and is done with side and top knives together with shovels. The blades of the knives are set so they will cut weeds between the two rows and on the sides of each bed. Two and four-bed tractor-powered cultivators are most common. Following this cultivation the beds frequently are chiseled; that is, two chisel-like blades are drawn through the soil to a depth of four to 6 inches between the two rows of each bed. After thinning, when the plants become larger, 2 to 6 cultivations are often made. These later practices may stir the soil from 1 to 3 inches deep. The primary purpose of cultivation is to destroy weeds, but other reasons are often given for tillage.
>
> "Crusting of the soil before the seedling emerges is believed to be detrimental to good plants. Some growers irrigate before thinning because this practice seems to be facilitated when the soil is moist; others irrigate after

*Access to these reports and permission to quote from them were given by Dr. F. J. Veihmeyer, Professor of Irrigation, College of Agriculture, University of California, who directed the experiments.

thinning because they believe that irrigation helps the plants to recover from the distrubance of the soil caused by thinning. The lettuce growers thus are not in complete agreement in their reasons for irrigation or cultivation practices, even when climates and soil conditions are comparable. Many growers believe that water applied to the soil when the heads are maturing is apt to make them soft and loose; they also think that when the moisture supply is plentiful the leaves are crisp and a lighter green than when the soil is dry. Premature production of seed stalks is believed to be due to unfavorable soil moisture conditions."

Comments by County Agent A. A. Tavernetti in a mimeographed "Guide to Irrigation of Lettuce in the Salinas Valley" are, by inference, disclosive of current irrigation practice affecting this crop. Paragraphs from this guide that appear to be especially pertinent are quoted below:

"The first use of irrigation water in the production of crops was solely for the purpose of replenishing moisture in the root zone. Irrigation systems as well as most practices in the use of irrigation water are based on this use alone. While this purpose of water is still the most important, yet as more and more information has been learned in the production of crops, the use of water for other purposes than merely replenishing moisture has become a general practice. It is estimated that almost one-half of the water applied to lettuce is for purposes incidental to supplying moisture to the plant.

"These extra water applications can seldom be timed with the need for moisture replenishment. As a result, soils on which lettuce is grown are subjected to amounts of water far in excess of that needed for plant growth.

"The duty of water for lettuce growing in the Salinas Valley has been reported in one publication as six feet per year or three feet per crop. The duty of water has little relation to its efficiency of water use. It merely represents the amount used in general practice regardless of whether such practices be good or bad.

(1) Beneficial Uses of Water

"Replenishing moisture in root zone. - A single crop of lettuce to headed maturity consumes only from 2-1/2 to 3 acre-inches of water. In order to make moisture continuously available in the root zone of the plant, a considerable wastage of water is unavoidable.

"The distribution of lettuce plant roots is more or less in a fixed pattern for a given soil condition at a given date; however, there is a wide variation in the root pattern in different soils as well as in the same soils at different seasons of the year.

"During winter months when the subsoil is water soaked and cold, the root pattern is shallow and spreading. In the early fall months, the roots develop at deeper depths and there may be less surface-feeding roots.

"The surface root development during winter months is not due as much to moisture being available at the surface as it is from unfavorable growing conditions at deeper depths. As the soil aerates and drys downward, root growth follows. If the surface soil should dry out too rapidly, there may be a temporary lag in growth of the plant until adequate roots have been established at lower soil levels. This condition is often mistaken for a need for more water, which when applied seldom effects any good but rather in retarding the correction which normally takes place.

"Most plants will grow equally well as long as a reasonable amount of root system is supplied with moisture, provided soil fertility, temperature, aeration and other growth factors are equally favorable. Unfortunately, these conditions may vary materially at different depth zones and at different seasons of the year. The most fertile part of a soil is usually at the shallower depths. If this area becomes dry, this rich source of plant nutrients may not be available to the plant. Following an irrigation, new roots develop immediately in this area. The subsequent growth response may be largely due to additional plant nutrients made available rather than to additional moisture.

"Since moisture is so intimately associated with other growth factors, it is not possible to consider it by itself in any recommendations concerning number of irrigations. To make adequate moisture alone available in the root zone, two irrigations following seed germination have usually been sufficient.

"Reduction in carrying quality of lettuce. - Experiments conducted with various numbers and times of irrigation as compared to no irrigation have invariably resulted in lettuce grown without irrigation being outstandingly better in carrying quality. Obviously, the yield on unirrigated soils may be small. In practice, there must be a compromise between loss of carrying quality and volume of production. If quality alone is the prime factor, a minimum amount of water that can be used, particularly as the lettuce approaches maturity, should give best results.

"Distributing fertilizers. - The application of fertilizers to growing lettuce necessitates the use of water to carry the fertilizers into the root zone of the plants. Readily soluble and nonfixing fertilizer materials such as nitrates ultimately come to rest in the soil where the water stops. Obviously, it is essential that such water remain within the main root zone of the plant. This zone is a relatively limited area in the upper regions of the soil. Any water penetrating below this region carries with it not only fertilizers applied but much of the natural fertility as well. This fertility will not then be available to the plants and in all probability lost forever.

"Many conditions of poor growth are often attributed to lack of moisture, whereas the problem is entirely one of fertility. With methods available for the simple and relatively inexpensive application of fertilizers at any time during the growing period, this condition can usually be quickly and properly remedied with a minimum amount of water.

"Germinating seed. - The actual amount of moisture needed to germinate lettuce seed is very small; however, the use of water to either pre-irrigate dry beds prior to seeding or to irrigate dry seeded beds accounts for the heaviest application of water in a single irrigation made to lettuce soils during the year. As much as 22 acre-inches of water in a single irrigation have been recorded. This application usually comes during the summer months following a period in which the soil has dried out, warmed up and aerated, resulting in a rapid accumulation of nitrates. Much of this accumulated fertility is washed out of the soil by irrigation water passing through it. Unfortunately, it is not apparent during the early growth of lettuce while the young plants have access only to the top, small "V" sections of the bed on which the seed has been planted. This area being above water in the furrow retains its original fertility or may even be enriched by the movement of water that has picked up fertility elsewhere moving into it by capillarity. As the lettuce grows and the roots extend beyond the bed area, deficiencies in soil fertility become apparent.

"The use of shallow, wide furrows in soil not too finely pulverized so that water can move through it readily tends to reduce the amount of water required in pre-irrigation.

"To germinate seed planted in dry soils, advantage should be taken of the 4 to 6 inches of additional movement of moisture that takes place after the flow in the furrow is cut off. Best results have been obtained from the use of a large head of water to force the flow to the end of the furrow quickly and then cutting the flow down so that percolation takes place uniformly along the full length of the furrow. When the soil shows wet to the seed row, the water should be cut off. In the course of a few days, the continued movement of moisture will have completely wetted the bed.

"In one experiment of 6 acres, conducted in the summer of 1941, a satisfactory yield was obtained by the use of the methods mentioned above with a total use of only 14 inches of water to germinate the seed, followed by three light irrigations during the growing period. The previous irrigation practices on this soil had required from 20 to 30 inches of water to accomplish the same purpose.

"Facilitating cultural operations. - Soils are often irrigated in order to make possible plowing or cultivating. Short, shallow runs spaced closely are desirable in reducing excessive applications.

"Leaching out detrimental salts. - This is not an intended practice in this area; however, it goes about of its own accord since if the amount of detrimental salts in irrigation water were not leached out or forced downward beyond the root zone, the accumulation in a short time would prove disastrous. Hardpan soils do not allow for subsoil leaching and under such conditions surface runoff accomplishes somewhat the same results.

"Overcoming conditions of growth. - Under cool climatic conditions, an irrigation may encourage heading of lettuce. The reverse may also be effected if the weather is warm. Tip burn sometimes may be overcome or prevented to a certain extent by keeping the surface soil moisture close to the field capacity at heading time. As yet, not sufficient information is available on these subjects to be certain of obtaining results.

(2) Detrimental Results of Irrigation

"Leaching. - As most vegetable soils are continuously at full moisture field capacity below the two foot depth zone, any single irrigation of more than 6 acre-inches may result in penetration below the root zone. One acre-inch of water penetrates 3 to 5 inches in heavy dry soil. On loam dry soil, penetration is from 4 to 5 inches. On the lighter phases, it is from 5 to 6 inches.

"A six inch application of water on loam soil if the soil is completely dry will penetrate to a depth of approximately 24 to 30 inches. This should be adequate for most vegetable crops. Any irrigation of more than 6 inches in a single application must be considered as excessive.

"The penetration of free water downward in loam soil has been found to be from 4 to 5 inches an hour; therefore, water running continuously in a furrow made in loam soil for a period of more than 6 hours would likely penetrate to depths below 30 inches.

"One heavy irrigation during the year may remove more plant nutrients from the soil than would be removed by several crops of lettuce.

"Stimulating effects of disease. - Sclerotinia (drop), mildew, and some similar diseases are stimulated by high humidity that results from surface evaporation following irrigation.

"Unfavorable physical conditions resulting from irrigation. - Puddling resulting from harvesting on soils that are wet or other operations when there is an excessive amount of moisture in the soil may decrease the growth of subsequent crops greater than the advantages gained from water application on the crop to which irrigation was made.

"Water is necessary to make available plant nutrients and plant growth factors; however, the net result to the soil of an irrigation is usually a loss, though at the time it may return an economic profit. The loss to the soil may not be apparent immediately but as irrigation continues over the years, the soil becomes less productive. As productivity decreases, the general practice has been to attempt to make the soil more productive by more irrigations, which merely adds to the problem.

"The use of water as a means of saving labor or as a cure-all for poor growing conditions may in the long run prove very expensive."

Data produced by the Soil Conservation Service canvass included reports from the Forebay Area not inconsistent with the extreme figures cited by Mr. A. A. Tavernetti and the College of Agriculture, but data applying strictly to the Pressure Area lettuce are indicative of a generally more economical application. Most of the Pressure Area reports indicated two irrigations for the spring crop with an average total of 13.7 inches. The summer crop was consistently reported irrigated three times for an average total of 23.3 inches. The few reports on lettuce in the East Side Area showed lower average totals (10.8 and 18.0). The Forebay Area lettuce, however, was irrigated more frequently (3.5 and 4 times, on the average) and received substantially larger average total amounts--31.1 inches and 37.4 inches, respectively--while third crops on two fields were irrigated 4 times and 2 times respectively for an average total of 50.3 inches. In the extreme case reported which represented a large 3-crop field, the yearly total was therefore in excess of 10-1/2 feet.

Results of the Soil Conservation Service canvass of lettuce irrigation are summarized in Table 6, previously set forth in Appendix A.

As noted by County Agent A. A. Tavernetti and the College of Agriculture, the irrigation given to germinate the seed is, in most cases, the heaviest of the several applications received by the crop. Growers who were interviewed for the Division of Irrigation explained other irrigations as needed to replenish moisture, effect fertilization, or hasten maturity of second cutting. Where preirrigation was practiced it had the purpose of building up depleted soil moisture or putting the soil in good working condition.

The carefully determined delivery to lettuce fields under observation by the Division of Water Resources of the California State Department of Public Works is summarized in Table 7 of Appendix A.

On the basis of the data report in Tables 6 and 7, supplemented by general observation, the conclusion is that lettuce is given about the following total depths of water yearly: Pressure Area, 32 inches; East Side, 40 inches; Lower Forebay, Upper Forebay, and Arroyo Seco, 54 inches.

Truck

Since much of the area with which this report is concerned can produce more than one crop a year, several other crops are grown on the lettuce land, either independently of or in rotation with lettuce. As stated by Knott and Tavernetti,*

> "The grower can work out a rotation with lettuce planted for harvesting in spring, summer or fall. To counteract the combined effect of irrigation and cultural and harvesting operations on the compaction of the soil during the growth of lettuce, it is well to rotate this crop with one that receives less working of the soil while wet.
>
> "One can grow the following crops for spring harvest and still allow sufficient time to mature a crop of lettuce during the summer and fall: lettuce, garden peas, carrots, spinach, sugar beets, garlic, vetch seed, and certain other seed crops. Possibilities for fall harvest after lettuce, green peas, tomatoes, potatoes, carrots, cauliflower, spinach, celery, broccoli, and cabbage.
>
> "Green manure crops are almost indispensable if lettuce is to be grown on the same soil over a period of years. More than two crops of lettuce should not be grown without at least one of green manure intervening, particularly if animal manure is not available. For green manure purple vetch and melilotus indica or mixtures of these two are used almost exclusively.
>
> "Since melilotus indica will not germinate satisfactorily in warm weather, its use is confined to winter. Mixtures of it with vetch for winter planting are common. At other seasons, purple vetch alone is used. An August seeding of vetch for plowing under in November or December fits well into planting operations.
>
> "Purple vetch, when seeded alone, is usually at the rate of 40 to 60 or more pounds per acre. First the seed is either drilled into the soil or broadcast, then ridges and furrows are made that cover the seed. The soil is irrigated to aid germination. Many growers prepare the soil and beds and drill the vetch in close-spaced rows and in the furrows."

Table 8 of Appendix A, prepared from data accumulated in the Soil Conservation Service canvass, indicates irrigation deliveries to several varieties of truck crops averaging in the Pressure Area, 8.5 inches for the spring crop and 10.8 inches for the summer crop. The single truck crop in the East Side Area for which estimates were obtained was 50 acres of radishes, 7 inches being given the field. Deliveries in the Forebay Area were much higher, averaging 32.8 inches for the spring crops and 40.8 inches for the summer crops. Confining the comparison to acreages that raised two crops in the year, the spring crops received 40 inches and the summer crops the 40.8 inches previously noted.

In the mapping of crops, celery was included in the lettuce category, being currently raised exclusively in the lettuce area and being given much the same irrigation allowance. This crop is, as a matter of fact, much more important than might be assumed from the submergence of its acreage figures in the lettuce tabulation. Several hundred acres are currently in the celery acreage in the Pressure Area. The single listing in the table, showing a summer crop of celery on 22 acres, therefore provides an inadequate indication of its appropriate water allotment. However, the six applications totaling 12 inches are probably representative of the Castroville section where the reporting farm is located. The size of the celery plant in its mature stages suggests a higher transpiration rate than that characterizing lettuce.

Of the other vegetable crops carrots are probably most important in point of acreage, though the cabbage-broccoli acreage is also rather extensive. The carrot acreage is about one-third the total mapped as truck in the Pressure Area. Two crops are commonly grown, with irrigations totaling about 10 or 12 applications. Furrows are used. This plant in its mature

*J. E. Knott and A. A. Tavernetti, "Production of Head Lettuce in California", Calif. Agr. Expt. Sta., Circ. 128.

stages covers the ground and probably offers higher transpiration opportunity than lettuce.

Cabbage, broccoli and cauliflower, potatoes, onions, and tomatoes have fluctuating importance depending on marketing prospects as well as rotation needs.

In summary: Truck crops are of third importance in point of acreage in the area surveyed, and of second importance in the Pressure Area. The lands involved are usually double cropped from March to October, 10 or 12 irrigations being given by furrows. A non-irrigated cover crop is grown the remainder of the year. As in the case of lettuce, applications in the East Side, Forebay and Arroyo Seco areas are usually numerous and involve more water than in the Pressure Area.

The use by truck crops under observation by the Division of Water Resources is summarized in Table 9 of Appendix A. All observed fields were in the Pressure Area.

On the basis of the data reported in Tables 8 and 9, supplemented by general observation, the conclusion is that truck crops are given about the following total depths of water yearly: Pressure Area, 30 inches; East Side Area, 36 inches; Forebay, Arroyo Seco, and Upper Valley areas, 50 inches.

Beans

Beans grown in the surveyed areas are mainly small whites, pinks and other dry varieties, and seed beans grown under contract with seed companies. (Pink beans are favored more in the Upper Valley, but some are grown in the surveyed areas below Soledad). Planting dates are around the middle of May and the varieties which do best are late-maturing types, yields of which give them preference.

Beans are planted in 26-inch rows or even closer (two 24-inch and a 28) and are so cultivated that two rows are on either side of one bed. This is accomplished by putting an irrigation furrow in alternate rows. The irrigation is thus furrow irrigation. Many farms have the water piped to the field, with distribution therefrom by diversion pipes. Runs are fairly long, in occasional instances up to 1/2 mile.

As in the case of the other crops, irrigation of beans in the Forebay, Arroyo Seco, and Upper Valley areas is much heavier than in the Pressure and East Side areas. This is brought out in Tables 10 and 11 of Appendix A.

No data on irrigation of beans in the Pressure Area were obtained in the canvass by the Soil Conservation Service, but two fields in the East Side Area, five in the Forebay Area, and six in the Arroyo Seco Area were represented. Beans grown in the Pressure Area are mostly planted on rested lettuce land and are usually irrigated twice beginning about June 1, though in some years only one irrigation is required. The crop is harvested about September. A grass cover crop is allowed to grow during the winter. In the East Side, Forebay, and Arroyo Seco areas about half the beans are irrigated four times, and the other land is double-cropped with peas or lettuce, six irrigations for the combination being customary.

From the data obtained by the Soil Conservation Service and those developed in the study by the Division of Water Resources, it is concluded that irrigation deliveries to beans probably average about as follows: Pressure Area, 10 inches; East Side Area, 22-1/2 inches; Lower Forebay Area, 24 inches; Upper Forebay Area, 40 inches; Arroyo Seco and Upper Valley areas, 40 inches.

Sugar Beets

While the acreage currently in sugar beets is greatly reduced from that reported only a few years ago, this crop may still be regarded as important. Under altered economic conditions the acreage devoted to it might experience a considerable expansion. The main present habitat of the crop is, however, the southern section of Salinas Valley, about five-eighths of the acreage reported in the Water Resources survey being in the Upper Valley Area south of the Forebay Area. About 60 per cent of the remaining sugar beet acreage is in the Pressure Area. The growing season for about 85 per cent of the Pressure Area plantings is from April to September, with about one-seventh of the acreage planted to a late crop. As in the case of most of the other crops, irrigations in the other areas are more numerous and total larger amounts of water than in the Pressure Area. In fact, near the mouth of the Salinas River, beets can be grown without irrigation.

Partly because of the long-continued position of this crop in the agriculture of Salinas Valley, most of the land on which beets are grown has been properly graded, permitting even distribution of irrigation water without flooding. The land is usually prepared by plowing in the fall or when the soil is dry, in order to condition it. Sub-soiling frequently follows the plowing, and land planes are used to remove irregularities of the surface. Deep chiseling in two directions further conditions the soil. The chisels are followed by harrows or ring rollers to break clods and compact the surface soil in the interest of soil moisture control.

The beets are grown on beds formed by ridges thrown up by lister shovels, rows in the beds being 12 to 14 inches apart, with 26 to 28 inches separating the beds. Distribution of water is by furrows, flow to them from the lateral ditches being controlled by portable metal dams with gates adjustable to permit maintenance of uniform heads accurately gaged. In early-season irrigation, tubes, pipes and flues through the ditch banks, siphons over it, or surface pipe with adjustable gates are useful. Sometimes the seed is planted on dry soil, immediately after which the field is irrigated to supply the moisture for germination. Following cultivation, thinning and hoeing, the sides of the beds are reshaped, and the irrigation furrows are reformed. After the first irrigation they are again reformed to permit adequate subsequent irrigation. Commercial fertilizer is applied by many growers following thinning, and water is applied as soon as possible after fertilization and hoeing.

As indicated in Table 12 of Appendix A, the beets receive from 1 to 4 or 5 irrigations, with applications totaling from a few inches in the Pressure Area to around four feet farther up the valley. Cover crops are widely used, the organic matter added by them maintaining the soil in good condition and increasing the benefits from the commercial fertilizer. The cover crop may be irrigated or not, but more than one irrigation is seldom considered necessary.

The results of the study by the Division of Water Resources as applied to sugar beets are summarized in Table 13 of Appendix A.

Artichokes

Artichokes are an important crop in the extreme northern end of the Valley, the entire 2942 acres shown for this crop being in the Pressure Area north of Salinas.

Irrigation is done in a method somewhat peculiar to this crop, involving considerable labor. A single furrow is opened down each row of plants. Short runs are made from rather

frequent cross ditches. A head of about 100 gallons per minute is turned in and permitted to reach the lower end of one run. When it has reached the lower end of the run, an irrigator begins cutting in the sides of the furrow so that water is flooded from the ditch to the plants on either side. This flooding and filling in of the ditch are carried on up the row to the entrance of the water from the cross ditch, where it is then cut into the furrows in the next row. After an irrigation, the entire surface is wet. This method is thorough but not efficient because of the labor expended in applying the water. Estimates made by the University of California as to time required to irrigate artichokes by this method were about 8-man hours per acre.

Cultural practices in the growing of artichokes are somewhat involved, as is suggested by the following program noted by the University of California in studies near Santa Cruz several years ago:

Date	Operation
April 29	Plowed and harrowed lengthwise direction of field.
May 23	Tops of plants cut about two inches below ground surface.
June 14	Plowed one furrow on each side of rows.
June 16	Cultivated both directions in field and one furrow made between rows.
July 3	Cultivated and furrowed out all plots.
July 21	Cultivated and furrowed out all plots.
Aug. 24	Cultivated and furrowed out all plots.
Sept. 4	Cultivated and furrowed out all plots.
Sept. 21	Harrowed all plots.
Sept. 29	Cultivated and furrowed out all plots.
Oct. 21	Cultivated and furrowed out all plots.
Nov. 10	Deep drain ditches plowed in between rows.

While some replacement each season is customary, the artichoke plant is a perennial and fields are replanted only at fairly long intervals--say 7 or 8 years. However, as indicated in the foregoing schedule of operations, the plants are cut off completely just below ground surface each spring, so that the growth of stalk and foliage is new thereafter. This operation usually occurs in April in Salinas Valley. The University's studies showed average application of 10.7 acre inches of water during one year and 11.2 inches the second year.

A single field was reported on in the canvass by the Soil Conservation Service. This was a 15-acre tract which received only two irrigations totaling 8 inches. Three fields were included in the study by the Division of Water Resources. Results of these observations are disclosed in Table 14 of Appendix A.

As indicated by Table 14, the somewhat common practice by the artichoke growers is to irrigate five times (infrequently six). No irrigations are given after the end of November.

When artichoke plantings are started, the new plants are given two fairly heavy early irrigations to establish the young shoots. These irrigations are given before June 1; after that date the regular schedule is followed.

From the available data, supplemented by general observation, the conclusion is that average practice involves delivery of about 20 inches of irrigation water to artichokes in this area.

Guayule

Guayule has had a long history in Salinas Valley. Being a desert plant, it is capable of thriving in the equable climate of the Valley without irrigation, though making a more rapid growth if irrigated. Having soil preferences different from those of lettuce and the truck crops, it is not their competitor, but during the war-time expansion it absorbed a considerable

acreage of so-called bean land.

The guayule acreage included in the crop survey was all operated by the United States Forest Service, under the war-time Emergency Rubber Project. The nurseries, acreage of which was several hundred acres, were irrigated by sprinkling systems and frequent applications of water, totaling large amounts, were made. The fields operated for rubber harvest were irrigated by the furrow method, water being obtained from pumping plants on leased properties.

In advising the emergency Rubber Project as to the probable irrigation needs of guayule for reasonably rapid production of rubber as contemplated by the original program, the Division of Irrigation in 1943 estimated that "the seasonal needs in the Lower Valley will be about 18 acre-inches per acre, and the seasonal needs of the Upper Valley will approximate 24 acre-inches per acre". (Soledad was the dividing point between Upper and Lower Valleys, with Arroyo Seco and tributary lands assigned to Upper Valley.) For reasons of economy of operation, these amounts were not provided by the Project during 1943-44. The weighted average of the first irrigation during that season, as delivered to 2317 acres of guayule, was 5.2 acre-inches per acre, and only two ranches were irrigated a second time. Meanwhile, however, experiments were conducted on several guayule plots in the lower valley, with water deliveries as indicated in Table 15 of Appendix A. While the mere fact that these deliveries were made does not establish proof that other amounts would not have had more productive results, the program followed seems to justify the conclusion that at least one acre-foot per acre was thought to be necessary to produce worth-while results north of the Upper Valley Area.

Much of the guayule acreage under control of the Emergency Rubber Project had been devoted to other irrigated crops prior to being leased by the Forest Service. Continuance of the project along its present lines is not assured, and some of the 8783 acres reported in the crop survey may revert to its former, or other, cropping. In that event, irrigation deliveries to the land may increase to their former amounts. A study by the Division of Irrigation in 1943 indicated an average irrigation application to former crops on lands leased for guayule of 15.5 acre-inches per acre in the Lower Valley, and 30.2 acre-inches per acre in Upper Valley. (The areas upon which the average were based were 2857 and 2802 acres, respectively.)

In the computations of water use by the crops appearing in the 1944 crop survey, 12 inches is assumed to have been delivered to guayule in each of the five areas.

Seed Crops

Seed crops were reported in only the Pressure and East Side Areas. Irrigation practice is about the same in both. The lands are single cropped, seed-crop planting being done in late winter and harvesting about August 15, except in the case of tomato seed, which is harvested about October 1. The irrigation season runs from April to July, after which the crop is allowed to mature dry. Customary irrigations are four. The seed crops are usually preceded by an early-fall cover crop which is irrigated once.

Only one seed tract was included in the study by the Division of Water Resources, this being 50 acres of tomatoes under Wells 4-D-10 and 4-D-12, in the East Side Area. This field received 5 irrigations totaling 15 inches, as follows: 0.9 inch; 3.0 inches; 3.5 inches; 3.8 inches; 3.8 inches. The preceding crop was winter-sown clover, which was not irrigated. The tomatoes were transplants, and the first irrigation followed immediately upon the transplanting.

(Field grown tomatoes are customarily irrigated four times; hence the practice for tomato seed does not differ significantly from that for fruit. Some tomatoes in the lowlands probably get some sub-irrigation and will need only one irrigation, but this crop is not prominent in the Pressure Area.)

The Soil Conservation Service canvass included two fields of seed peas in the East Side Area, one being 50 acres and the other 120 acres. Each tract received only two irrigations, being planted in December and harvested in May and June, respectively. The 50-acre field was given 8 inches in all; the other, 10 inches.

It is believed that these limited data do not disclose the average deliveries to seed crops in the Pressure and East Side Areas. A more appropriate average for seed crops in the Pressure Area is 20 inches, and in the East Side Area, 24 inches. Seeds raised in the Upper Valley area also receive about 24 inches.

Orchards

Orchards do not occupy an important acreage north of the Forebay area. More than half of the acreage devoted to orchards is south of Greenfield in the Upper Valley. The 250 acres in the Pressure Area represents principally large walnut trees. Deciduous trees elsewhere include apricots, prunes, apples, vineyards, almonds and young walnuts.

No orchards were represented in the study by the Division of Water Resources, and only one was involved in the canvass by the Soil Conservation Service. This was a 75-acre walnut grove in the East Side Area, which receives about 15 acre-inches of water per acre in three equal irrigations. Distribution is by furrows from a concrete pipe system.

This amount of water is about what the Division of Irrigation considers an adequate irrigation allowance for deciduous crops throughout the valley, and accordingly it has been used in the computations of average deliveries in each of the major areas.

Grain

Grain as an irrigated crop is of scant importance, only some 1050 acres being shown in this classification in the 1944 crop survey. While the one small Arroyo Seco field (13 acres) of barley that was reported in the Soil Conservation Service canvass was irrigated three times with a total of 24 inches of water, the more common practice is to irrigate grain only once with about six inches, this amount, added to winter precipitation, being sufficient to mature a crop. Six inches is therefore considered an average irrigation allowance for grain throughout the surveyed area.

Summary

The following tabulation shows, in summary, conclusions as to average seasonal deliveries of irrigation water to the different crops included in the 1945 survey, by major areas.

Estimated Seasonal Number of Irrigations and Total Water Applied to Agricultural Crops in Major Areas of Salinas Valley, California

Crop	Pressure		East Side		Lower Forebay		Upper Forebay		Arroyo Seco		Upper Valley	
	No.	Inches	No.	Inches	No.	Inches	No.	Inches	No.	Inches	No.	Inches
Alfalfa	7	24	7	36	8	42	8	42	8	42	8	42
Lettuce	7	32	8	40	8	54	8	54	8	54	-	--
Truck	10	30	10	36	10	50	10	50	10	50	10	50
Beans	2	10	2	22½	4	24	4	40	4	40	4	40
Sugar Beets	2	21	4	24	5	60	5	60	5	60	5	60
Artichokes	5	20	-	--	-	--	-	--	-	--	-	--
Guayule	2	12	2	12	2	12	-	12	2	12	2	12
Seeds	5	20	6	24	-	--	-	--	-	--	6	24
Orchards	3	15	3	15	3	15	3	15	3	15	3	15
Grain	1	6	1	6	1	6	1	6	1	6	1	6

The following tabulation shows the effect of applying the averages in the foregoing table against the crop acreages reported in the 1944 cultural survey.

Estimated Seasonal Total Deliveries of Irrigation Water to Agricultural Crops in Major Areas of Salinas Valley, California in 1944.

Crop	Pressure	East Side	Lower Forebay	Upper Forebay	Arroyo Seco	Upper Valley	Total Valley
	Acre-feet	Acre-feet	Acre-feet	Acre-feet	Acre-feet	Acre-feet	Acre-feet
Alfalfa	4,402	5,934	8,488	9,741	10,489	7,063	46,117
Lettuce	51,885	6,507	10,580	900	1,588	---	71,460
Truck	22,742	4,242	11,717	9,725	4,900	6,312	59,638
Beans	9,313*	13,215	5,654	8,066	27,913	21,600	85,701
Sugar Beets	6,291	1,074	5,325	2,490	865	49,465	65,510
Artichokes	4,903	---	---	---	---	---	4,903
Guayule	2,927	1,599	2,462	640	1,057	98	8,783
Seeds	907	218	---	---	---	214	1,339
Orchards	312	351	666	221	530	1,652	3,732
Grain	76	118	54	---	22	254	524
Total	103,758	33,258	44,946	31,783	47,364	86,658	347,767

*7,126 acres at 10 acre-inches per acre plus 1,800 acres at 22½ acre-inches per acre.

By the computation producing the foregoing tabulation, crops in the Pressure Area received 103,758 acre-feet; East Side crops, 33,258; the Forebay, 76,729; Arroyo Seco, 47,364; Upper Valley, 86,658. In the Pressure Area, lettuce was the recipient of almost exactly half the total irrigation deliveries, and lettuce and truck combined received almost three-fourths (71 per cent) of that total. In the East Side Area, beans were the heavy recipient; in the Forebay Area, truck; and in the Arroyo Seco and Upper Valley areas, beans. In the total, beans led, with lettuce in second place and sugar beets third.

Comparison of the delivery figures given above with the area figures in Table 4 indicates the following averages.

Pressure Area	2.07 acre-feet per acre
East Side Area	2.19 acre-feet per acre
Lower Forebay Area	3.05 acre-feet per acre
Upper Forebay Area	3.51 acre-feet per acre
Arroyo Seco Area	3.24 acre-feet per acre
Upper Valley Area	3.95 acre-feet per acre
Total Area	2.77 acre-feet per acre

While the data obtained in the Soil Conservation Service canvass and the measurements made in the study of the State Division of Water Resources are neither separately nor together sufficiently voluminous to provide authentic averages indicative of irrigation practice as

applying to some of the crops, they do provide basis for two important conclusions: (1) Irrigation deliveries in the Pressure and East Side Areas are substantially lighter than those in the Forebay and Arroyo Seco Areas; (2) practice in the entire area surveyed is nowhere uniform from farm to farm, applications both in number and amount being affected by individual circumstances, convenient and preference in pronounced degrees. The units set out above are therefore reflective of the judgment of those who are responsible for this report as well as of the statistical data.

A third conclusion seems obviously justified, however, by the data and general observations of irrigation practice in the valley. This conclusion is that notwithstanding the apparent economy of irrigation practice in the Pressure Area when compared with that in the three southern areas, total irrigation applications are still much greater there than can be justified by the known consumptive use requirements of the crops involved. This is definitely disclosed in the chapter on Consumptive Use of Water, which follows.

CONSUMPTIVE USE OF WATER*

In water utilization investigations of areas such as Salinas Valley, consumptive use of water is one of the important factors to be considered. From a valley-wide standpoint, consumptive use includes all transpiration and evaporation losses from lands on which there is growth of vegetation of any kind, whether agricultural crops or native vegetation, plus evaporation from bare land and from water surfaces. The water consumed by native vegetation, evaporated from bare and idle land surfaces and from water surfaces may be designated as "non-beneficial" consumptive use. The term "consumptive use" in this report is considered synonymous with the term "evapo-transpiration" and is defined as: The sum of the volumes of water used by the vegetative growth of a given area in transpiration or building of plant tissue and that evaporated from adjacent soil, snow, or intercepted precipitation on the area in any specified time. If the unit of time is small, such as a day or a week, the consumptive use is expressed in acre-inches per acre or depth in inches; whereas, if the unit of time is large, such as a crop growing season or a 12-month period, the consumptive use is expressed as acre-feet per acre or depth in feet. The total consumptive use for a given area is expressed in acre-feet.

The processes of evaporation from a free water surface and plant transpiration are similar in that each is influenced by climatic conditions. Both evaporation and consumptive use (evapo-transpiration) are influenced by temperature, humidity, wind movement and precipitation. The quantity of water transpired by plants depends upon the amount of water at their disposal as well as on temperature and dryness of the air, the intensity of sunlight, the wind movement, the length of growing season, the stage of the development of the plant, the amount of its foliage, and the nature of its leaf.

General Procedure

Various methods have been used to determine the amount of water consumed by native vegetation and agricultural crops. Regardless of the method, the problems encountered are numerous and considerable time is required to make satisfactory measurements of consumptive use. The source of water used by plant life, whether from precipitation alone, irrigation plus rainfall, ground water plus precipitation, or irrigation plus ground water plus rainfall, is a factor influencing the selection of a method. Unit values of consumptive use may be determined for different kinds of native vegetation and agricultural crops by soil moisture studies, lysimeter or tank measurements, analysis of irrigation data, analysis of climatological data, and other methods. Unit values observed in one area may be used to estimate consumptive use in other areas having somewhat similar climatic conditions, provided temperature and precipitation records are available for both areas. For irrigated crops, data on depth of irrigation water applied, number of irrigations per year, irrigation efficiency, water-holding capacity (field capacity) of soil and length of growing season may be used in estimating unit values of consumptive use.

The results of unit consumptive use determinations by the methods described above may be applied to large valley areas such as Salinas Valley by the "integration method" to compute

* By Harry F. Blaney, Senior Irrigation Engineer, Division of Irrigation, Soil Conservation Service, United States Department of Agriculture.

the total amount of water consumed for a given area in acre-feet. Briefly stated, consumptive use for a specified time, as determined by the integration method, is the summation of the products of consumptive use for each crop times its area, plus the consumptive use of native vegetation times its area, plus water surface evaporation times water surface area, plus evaporation from land times its area. Before this method can be used it is necessary to know the area of agricultural crops, native vegetation, water surfaces and other classifications, as well as the unit consumptive use for each classification.

The results of a survey of water-consuming areas in Salinas Valley by the Division of Water Resources, Department of Public Works, State of California are previously summarized in Table 4 in Appendix A. Salinas Valley has been divided into five sections : 1-Pressure Area; 2-East Side Area; 3-Forebay Area; 4-Arroyo Seco Cone; and 5-Upper Valley Area, as hereinbefore shown on Plate 1.

Since no measurements have been made of consumptive use of water in Salinas Valley, estimates of unit values in this report are made by analyses of temperature, precipitation and irrigation data for Salinas Valley in comparison with similar data for San Luis Rey Valley and other areas where measurements of consumptive use have been made.

Neglecting the unmeasured factors, consumptive use varies with the temperature, the daytime hours and available moisture (precipitation and/or irrigation). By multiplying the mean monthly temperature (t) by the monthly per cent of daytime hours of the year (p), there is obtained a monthly consumptive use factor (f). Then it is assumed that the consumptive use varies directly as this factor, when an ample water supply is available. Expressed mathematically, U=KF=sum of kf where:

U = Consumptive use of crop (or evaporation from water surface) in inches for any period.
F = Sum of the monthly consumptive use factors for the period (sum of the products of mean monthly temperature and monthly per cent of annual daylight hours) (t x p).
K = Annual empirical coefficient.
t = Mean monthly temperature in degrees Fahrenheit.
p = Monthly per cent of daytime hours of the year.
$f = \frac{t \times p}{100}$ = monthly consumptive use factor.
k = Monthly empirical coefficient.

Briefly, the procedure is to correlate existing consumptive use data with monthly temperature, per cent of daytime hours, precipitation and growing (or irrigation) season. Coefficients are developed by dividing the unit consumptive use factor, or $K=\frac{F}{U}$. This method is used for estimating unit values for evaporation, native vegetation and alfalfa. Unit values for other crops are estimated by analyzing irrigation data as described later in this chapter.

The normal irrigation season in Salinas Valley usually extends from April 1 to October 31. Therefore, consumptive use is determined for winter period, November 1 to March 31, irrigation season (summer period), April 1 to October 31, and for the entire year.

Climatological Records

Precipitation and temperature records have been kept at Salinas for 72 years and at King City for a number of years. Observations at Soledad were discontinued some years ago. Precipitation records for 42 years are available at Soledad. The normal monthly precipitation at Soledad for a 72-year period has been computed from the ratio of available records at Soledad and Salinas. The normal monthly temperatures at Soledad have been taken as the average of Salinas and King City.

Table 16 previously set forth in Appendix A gives the normal monthly temperature and precipitation, per cent of daytime hours and calculated consumptive use factor for Salinas. Similar data are shown in Table 17 in Appendix A for the seasonal water years 1943-44 and 1944-45. These data are used to estimate consumptive use in the Pressure and East Side areas.

Estimated normal monthly temperature, precipitation, per cent of daytime hours and consumptive use factor for Soledad are presented in Table 18 of Appendix A. Similar information for 1943-44 and 1944-45 water years is shown in Table 19 of Appendix A. These data are used in estimating consumptive use in the Forebay and Arroyo Seco areas.

Table 20 of Appendix A shows the normal monthly temperature and precipitation, per cent of daytime hours and calculated consumptive use factor for King City. Similar information for 1943-44 and 1944-45 water years is shown in Table 21 of Appendix A.

Evaporation from Water Surface

No long period evaporation measurements have been made at Salinas. Fragmentary records for less than a year have been kept at different locations on the east mesa of the valley but these are not considered an adequate base for estimating normal monthly evaporation. Evaporation measurements made for several years from Weather Bureau pans in San Luis Rey Valley near Oceanside and at Newark in the coastal area north of Salinas are available. Climatic conditions in these areas are somewhat similar to those in Salinas Valley. The mean annual temperature at Newark is 56.9°F. for the period of record as compared to a normal annual temperature at Salinas of 56.5°F.; hence the observations at Newark are used to compute the evaporation in Salinas. Table 22 of Appendix A shows observed monthly evaporation and temperatures and computed monthly consumptive use factors and coefficients at Newark. The coefficients were determined by dividing the monthly evaporation by the consumptive use factor. Evaporation at Salinas and Soledad was computed by multiplying the consumptive use factors by these coefficients as indicated in Table 23 of Appendix A. The computed evaporation at Salinas is considered applicable to the Pressure and East Side areas, and at Soledad at the Forebay and Arroyo Seco areas. In a like manner, evaporation in the Upper Valley area may be computed from temperature records for King City.

Native Vegetation on the Valley Floor

During the past 18 years the Division of Irrigation, in cooperation with the California Division of Water Resources, has investigated the consumptive use of water by native vegetation. Some of the results for California and other western states have been summarized in the State Division of Water Resources Bulletin 50. According to this report, the relation of plant communities to moisture supply is one of the outstanding characteristics of growth of natural vegetation. While individual species are largely restricted to favorable physical environments, the principal condition that governs the distribution of vegetative groups is the amount of available moisture. Each species responds to individual water conditions for its most favorable growth and its widest distribution.

Natural vegetation grows under moisture conditions that are always changing. Plants that do not subsist on ground water but depend upon moisture held by the soil particles may have an abundant supply at one time and suffer a scarcity at another. Ground water fluctuates and

roots in contact with it are alternately wet and dry. Soil moisture is dependent upon precipitation, but evaporation, transpiration, percolation, and run-off cause its uneven distribution in the soil.

In arid areas moisture is retained in the upper soil horizon, and the vegetation is confined to those species which are adapted to extreme eccnomy of water. In areas of greater precipitation, deeper penetration results in plant roots drawing upon a greater volume of soil moisture. In low places a concentration of moisture takes place and ground water areas support those plants which use more water than dry-land plants. Finally the water-loving plants, living with their roots in water, are large consumers of water.

No measurements have been made of evapo-transpiration by native vegetation in Salinas Valley. However, as indicated above, climatic conditions in the lower San Luis Rey Valley near Oceanside, California are somewhat similar to those in the lower Salinas Valley. Therefore, the results of evapo-transpiration studies made by the Division of Irrigation in cooperation with the Division of Water Resources are used to estimate consumptive use of water in Salinas Valley by the method previously described.

Native vegetation on the floor of Salinas Valley was surveyed and classified by the Division of Water Resources as: swamp, dense trees-brush-grass, medium brush-tree-grass, and sparse brush-grass. (See Table 4 in Appendix A)

Swamp Areas

The results of observations in San Luis Rey Valley on temperature and consumptive use of water by tules growing in a tank (six feet in diameter and six feet deep, located in a swamp) are shown in Table 24 of Appendix A, together with computed monthly consumptive use factors and coefficients. By applying these coefficients to the consumptive use factors at Salinas and Soledad, estimates have been made of monthly consumptive use of water by swamp vegetation, as shown in Table 25 of Appendix A. Consumptive use factors at King City may be used to compute consumptive use for the Upper Valley Area.

Trees-brush-grass

Some areas in Salinas Valley are covered with growths consisting of native trees intermingled with grasses and brush of varying density, the variation being governed by the available water supply. In those areas underlain by a high water table the growths are dense, and as the terrain rises toward the hills and distance to the water table increases, vegetation becomes less dense and changes to a species having roots developed for obtaining water from greater depths. This arrangement results in irregular zones of vegetation, according to the ability of the roots to reach the ground water levels. Exceptions occur in some places as a result of soil types. In the Salinas Valley there are areas where ground water is near enough to the ground surface to support luxuriant growth of vegetation, but owing to lack of fertility in the soil the vegetation is sparse. These areas consist in general of sandy or gravelly soils which have been deposited by recent flood flows.

In mapping areas of trees intermingled with grasses and underbrush the growths were classified as dense, medium or light. In most cases there was no distinct dividing line between the classifications and one graded more or less gradually into another. In places where there

was abrupt change in topography, soils, or other features, the dividing line was [illegible], but this was the exception rather than the rule.

Willows, cottonwoods, and baccharis were the predominating type of trees, and although they drop their leaves and become dormant for about three months during the winter, consumptive use continues in the areas they occupy, owing to growths of grasses, weeds and underbrush. The lands may be considered as having a double crop with the trees using water during the summer periods and the grasses and underbrush using it during the winter. There was, of course, much overlapping of the two crops.

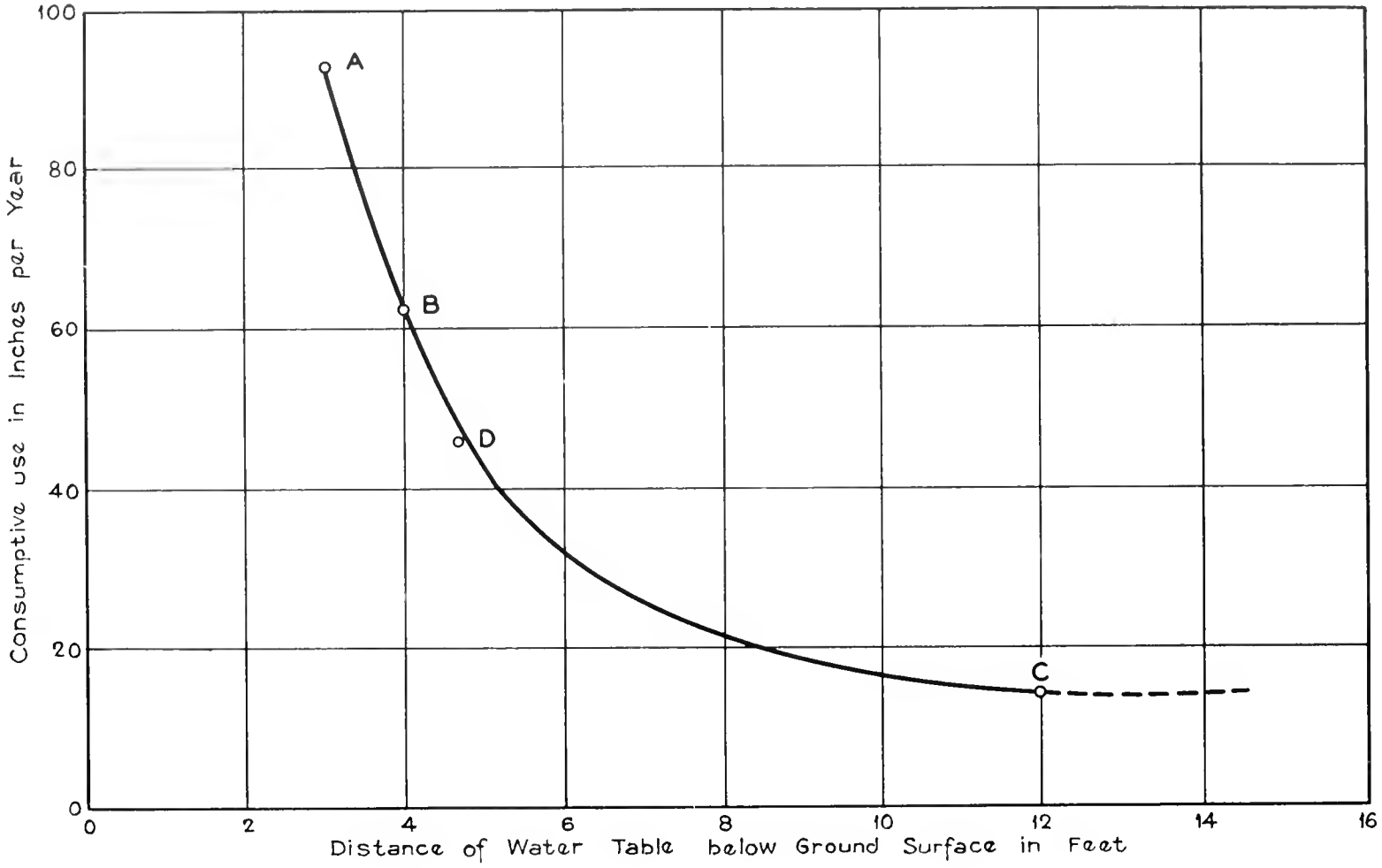
To estimate the consumptive use of intermingled native trees, brush and grass, data obtained from studies in Bonsall Basin, San Luis Rey Valley, were employed.

In San Luis Rey Valley an intermingled growth of cottonwood, willow trees and grasses (similar to growth in Salinas Valley) was grown in a tank located in natural environment. The water table in the tank was held for two years at 3 feet below the ground surface and for another two years at 4 feet below the ground surface. On the basis of the information presented, the annual use of water by native vegetation with water table at 3 and 4 feet averages 92.7 and 62.5 inches, respectively.

Plotting the observed data results in two points designated "A" and "B" on Plate 16. In order to complete the curve it was necessary to estimate a third point. This third point, "C", was determined on the assumption that valley vegetation draws little if any water from the ground water when the water-table is at a depth of 12 feet or more. Where the water-table depth is more than 12 feet, the vegetation depends wholly or very largely on rainfall which has been stored in the soil. Previous investigations in Santa Ana Valley indicated that in soil consisting of sand of variable texture to a depth of 12 feet or more, the major root activity of native vegetation existed in the zone from ground surface to a depth of 11 feet. The consumptive use consisted entirely of rainfall and amounted to as much as 14 inches in one year without penetration below the root zone. Point "C" on Plate 16 was therefore set at 14 inches of consumptive use with a water table at 12 feet. The consumptive use for areas with water-tables at greater depths than 12 feet would be the same and consist entirely of rainfall. In years of excessive precipitation there would be contribution to the ground water and in years of low precipitation the consumptive use could not exceed the rainfall. The curve does not necessarily apply where the water table depth is less than three feet, for the reason that the type of vegetation changes to swampy growths and there is more or less direct evaporation from the soil by capillary action.

Another point on the curve may be obtained from the data secured at the abandoned well in Bonsall Basin where a water level recorder was maintained and the consumptive use computed from the diurnal fluctuations of the water table. The use of water as determined by this method was 45.40 inches depth per year with an average distance to ground water table of 4.7 feet. This point is shown on Plate 16 as "D".

Table 26 of Appendix A shows the results of observed and consumptive use of water by intermingled growth of trees and grasses in a tank with the water table at four feet below the ground surface in natural environment in San Luis Rey Valley and computed monthly coefficients. These consumptive use data are considered applicable to areas in Salinas Valley where dense growth occurs along the streams and the depth to water table ranges from three to five feet with an average depth of four feet.



CONSUMPTIVE USE BY NATIVE VEGETATION
SAN LUIS REY VALLEY, CALIFORNIA

An estimate of monthly consumptive use of water by dense growth of trees-brush-grass in the Pressure and East Side areas and the Forebay and Arroyo Seco areas of Salinas Valley, based on the San Luis Rey Valley studies and temperature records, is shown in Table 27 of Appendix A. In a like manner consumptive use in the Upper Valley Area may be computed.

From the curve (Plate 16), the annual use of water in San Luis Rey Valley by medium brush-trees-grass (in areas with a water table ranging from 4 to 7 feet) is taken as 36 inches, and use by sparse brush-grass (in areas with a water table ranging from 6 to 10 feet) is shown as 21 inches.

These values for medium and sparse vegetation are transferred to Salinas Valley by means of the ratio of the consumptive use factors at Salinas to those at San Luis Rey. In estimating the seasonal consumptive use for sparse vegetation, consideration was given to the amount of moisture available from precipitation during the winter and summer periods.

Estimates of normal annual consumptive use of water by trees-brush-grass growing in Salinas Valley based on the San Luis Rey Valley data, in areas with the water table at various depths are given in Table 28 of Appendix A.

Irrigated Crops

Investigations of use of water by irrigated crops have been conducted for many years in California by the Division of Irrigation in cooperation with the State Division of Water Resources or the California Agricultural Experiment Station. The experimental work has not been limited to use-yield investigations and the ascertainment of the amounts of water applied, but has included determination of evapo-transpiration by soil moisture or tank studies in some areas. However, the only specific data available as to the consumptive use of water by agricultural crops in Salinas Valley are the results of determination made by the California Agricultural Experiment Station on lettuce.

As heretofore indicated, unit consumptive use may be estimated by analyses of irrigation data, climatological records or combination of both. Careful consideration should be given to temperature, length of growing season, distribution and amount of precipitation, kind of crop, number of irrigations, depth of water applied, irrigation efficiency, and evaporation after rainfall and irrigation. In areas of high water table, deep rooted crops such as alfalfa may secure moisture from ground water. Irrigation and other data in Salinas Valley have been collected and tabulated by the Soil Conservation Service, as previously described. The irrigated areas have been mapped by members of the State Division of Water Resources staff and the acreages determined under the following classifications: alfalfa, lettuce, truck, beans, sugar beets, artichokes, guayule, seeds, orchards, and grain.

The annual consumptive use has been divided into two periods: "winter", November 1 to March 31, the season when most of the precipitation occurs; and, "summer", April 1 to October 31, which is the usual irrigation season.

Precipitation is a large factor in winter consumptive use. Studies in southern California indicate that during the winter months evaporation after each rainstorm is about 0.5 inch and evapo-transpiration by grass, grain or cover crops is approximately 2 inches per month with normal distribution of precipitation. The normal precipitation for the winter period (November 1 to March 31) is: Salinas, 11.39 inches; Soledad, 7.61 inches, and King City, 9.16 inches.

On most of the irrigated lands, crops or cover crops are growing throughout the year. Some moisture from fall irrigation may be carried over for winter use, and some precipitation during the winter months which is not used by winter crops may be available for use during the summer period. Measurements in southern California indicate the evaporation after each irrigation usually ranges from 0.5 to 1.0 inch depending upon soil, percentage of surface soil that is wet, length of time of irrigation and temperature.

If all the water delivered to a farm could be absorbed by the roots of the crop and transpired by the foliage, irrigation efficiency of 100 per cent would be reached, but in actual practice some is lost by evaporation and some may be wasted by deep percolation below the root zone or by surface runoff. Studies in California indicate that with the best equipment for distributing water and its most skillful application in moistening the soil, it is seldom practicable to utilize more than 75 per cent. With poor equipment and less skillful irrigators, the efficiency may drop to 30 per cent or less.

Irrigation practices for different crops in Salinas Valley, which may influence the amount of consumptive use, have been previously discussed. The following estimates of unit values of consumptive use are based on normal conditions.

(1) Alfalfa

Information available indicates that the depth of water applied and the number or irrigations varies considerably for alfalfa in Salinas Valley. Also in areas of high water this crop obtains some moisture from ground water. Therefore, estimates of consumptive use of water for alfalfa will be computed from consumptive use factors for Salinas Valley (f) and coefficients (k) determined by experiments in other areas. As heretofore indicated, there is a definite relation between monthly consumptive use factor (f) and monthly consumptive use of water (u), and this is expressed mathematically by the formula $u=kf$. From data now available, it is estimated that the monthly coefficient (k) for alfalfa in Salinas Valley ranges from 0.40 in January to 0.85 in July.

Table 29 of Appendix A shows the computed normal unit monthly consumptive use of water by alfalfa values for five areas in Salinas Valley. In the Forebay and Arroyo Seco areas the precipitation was not sufficient to take care of the water requirement during the winter period (November to March inclusive).

(2) Lettuce

On lettuce land, in the Pressure Area, a cover crop is grown during the winter. Two-thirds of the land depends upon precipitation for moisture, while one-third receives moisture from one 6-inch irrigation in October. Experiments in southern California indicate that a cover crop will use about 2 inches of water per month. Therefore, the winter consumptive use is estimated as 8 inches for two-thirds the lettuce land and 10 inches for the remaining third, which receives moisture from irrigation.

During the irrigation season, two crops of lettuce are grown on two-thirds of the land, with eight 4-inch irrigations, while on the remaining third a single crop of lettuce is grown with five 4-inch irrigations in the summer and one 6-inch irrigation in October to supply moisture for the winter cover crop.

Irrigation experiments made by the California Agricultural Experiment Station indicate that the consumptive use of water by lettuce in the Pressure Area of Salinas Valley will

not exceed 4 inches per crop during the actual growing season. Consumptive use was determined by soil moisture studies and does not include evaporation losses from soil after pre-irrigation and from free water surface during irrigation. These losses are estimated to be 1.5 inches for a single crop. It is estimated that the total consumptive use for irrigation season (April to October inclusive) is 11 inches for the double-cropped land and 6.5 inches for the single crop land with late fall irrigation.

(3) Other Crops

No experimental data on consumptive use are available for other crops in the valley. Estimates of consumptive use are based on general irrigation practice, precipitation and length of growing season for winter and summer crops. An example of computation for double-cropped land growing truck in Pressure Area is as follows:

Winter period (November 1 to March 31)		
Evapo-transpiration, cover crop 4 months		4.0 inches
	Sub-total	4.0 inches
Irrigation season (April 1 to October 31)		
Depth of water applied, 10 irrigations at 3 inches, 30 inches.		
Assumed irrigation efficiency* 40 per cent.		
Estimate of transpiration 0.40 x 30 =		12.0 inches
Estimated evaporation loss:		
2 irrigations, 1 inch each		2.0 inches
8 irrigations, 1/2 inch each		4.0 inches
	Sub-total	18.0 inches
Annual Consumptive use, Total		26.0 inches

Unit values of consumptive use for other crops and for all the areas are estimated in a similar manner.

(4) Unit Values of Consumptive Use

Summaries of estimated normal unit values of consumptive use of water by irrigated crops for winter, summer and annual period in the Pressure, East Side, Forebay, Arroyo Seco and Upper Valley areas are shown in Tables 30 to 34, inclusive, previously set forth in Appendix A.

Other Classifications

Other water using areas which have not been heretofore discussed include areas mapped as irrigable dry-farm and grass, river channel, wasteland, town and farm lots and roads and railroads.

(1) Irrigable Dry-farm and Grass

Most of the dry farm and grass areas in Salinas Valley are found on the hillsides and benches where no underground water is available for plant growth. The use of water by these areas is dependent upon the amount and distribution of rainfall. The areas in this classification consist of grain and native grass. These crops have their greatest growing period during the winter and spring months.

* Irrigation efficiency is defined as the percentage of water applied that can be accounted for as soil moisture increase in the soil occupied by the principal rooting system of the crop.

Considering information from studies in southern California and the distribution of rainfall in Salinas Valley, the normal annual unit consumptive use of irrigable dry farm and grass lands is estimated to be 1.1 feet in the Pressure and East Side areas, 0.75 foot in the Forebay and Arroyo Seco areas and 0.83 foot in the Upper Valley Area.

(2) River Channel

In estimating the consumptive use (or evaporation only in this case) of the river channel, the fact that it is alternately wet and dry in most places was taken into consideration. The stream throughout most of its length is intermittent, flowing during the late winter months and spring months, January 1 to June 30, and mostly dry during the period, July 1 to December 31. At narrow constricted places the water table is held closer to the ground surface and consequently surface water here appears earlier in the winter and lasts longer in the spring. At a few places, flowing water may occur the year round. The normal annual unit consumptive use of river channel is estimated to be 1.74 feet in the Pressure and East Side area, 1.78 feet in the Forebay and Arroyo Seco areas and 1.81 feet in the Upper Valley area.

(3) Waste Land

Areas placed under "waste land" are bare and consist of sandy or rocky soils. In many cases they are subject to overflow from the river or tributary streams during periods of high water. The normal annual unit consumptive use is estimated to be 0.50 foot in the Pressure and East Side areas, 0.40 foot in the Forebay and Arroyo Seco areas and 0.45 foot in the Upper Valley Area.

(4) Town and Farm Lots

Areas mapped as "town and farm lots" are assigned an annual unit consumptive use of 2.0 feet. This allows for an actual use of 1.5 feet with 0.5 foot lost by evaporation after rains. It is estimated that 25 per cent of the use occurs during the five month winter period and 75 per cent during the period, April 1 to October 31.

(5) Roads and Railroads

All improved roads and railroad right-of-ways are included under this classification. The loss of water from these areas is primarily by evaporation after rains. An annual unit consumptive use of 0.5 foot is assigned to these areas. The total acreage involved is small.

(6) Summary of Unit Consumptive Use

Normal unit consumptive use values determinations for winter, summer and annual periods for the Pressure, East Side, Forebay, Arroyo Seco, and Upper Valley areas are summarized in Table 35 of Appendix A.

Estimates of Consumptive Use by the Integration Method

Before the integration method can be used to determine the total consumptive use for given areas, it is necessary to know the unit consumptive use of water and the acreages of irrigated crops, native vegetation, water surface, and other classifications.

In the previous sections of this report, normal unit consumptive use values have been developed for various classes of irrigated lands and other water-using areas in Salinas Valley. These are shown in Tables 23, 25, 28, 30, 31, 32, 33, 34, and 35, previously set forth in Appendix A. Acreages of the various water-consuming areas, mapped in 1944, have been shown in Table 4 of Appendix A. Applying the normal unit consumptive use values for each land use area, the total estimated normal consumptive use was computed for the pressure, East Side, Forebay, Arroyo Seco, and Upper Valley areas as shown, respectively, in the following five tabulations:

Estimated Normal Consumptive Use of Water in the Pressure Area, Salinas Valley, California

Classification	Area	Winter Consumption*		Summer Consumption**		Annual Consumption	
		Unit	Total	Unit	Total	Unit	Total
	Acres	Feet	Acre-Feet	Feet	Acre-Feet	Feet	Acre-Feet
IRRIGATED CROPS							
Alfalfa	2,201	0.74	1,628	1.92	4,227	2.66	5,855
Lettuce (2/3)	12,971	.67	8,690	.91	11,804	1.58	20,494
Lettuce (1/3)	6,486	.83	5,383	.57	3,697	1.40	9,080
Truck (3/4)	6,820	.67	4,570	1.50	10,230	2.17	14,800
Truck (1/4)	2,277	.83	1,890	1.00	2,277	1.83	4,167
Beans (81%)	7,126	.67	4,774	.75	5,345	1.42	10,119
Beans (19%)	1,800	.58	1,044	1.00	1,800	1.58	2,844
Beets (85%)	3,056	.83	2,536	.92	2,812	1.75	5,348
Beets (15%)	539	.67	361	1.13	609	1.80	970
Artichoke	2,942	.33	971	1.21	3,560	1.54	4,531
Guayule	2,927	.83	2,430	.83	2,429	1.66	4,859
Seeds	544	.67	365	1.04	565	1.71	930
Orchards	250	.67	167	1.33	333	2.00	500
Grain	151	.67	101	.72	109	1.39	210
Sub-total	50,090		34,910		49,797		84,707
IRRIGABLE DRY FARM AND GRASS	12,540	0.50	6,270	0.60	7,524	1.10	13,794
NATIVE VEGETATION (Valley Floor)							
Swamp	2,674	0.91	2,434	3.60	9,626	4.51	12,060
Dense trees-brush-grass	2,669	.76	2,028	4.08	10,890	4.84	12,918
Medium brush-trees-grass	1,993	.90	1,794	1.89	3,766	2.79	5,560
Sparse brush-grass	1,205	.83	1,000	.80	964	1.63	1,964
Sub-total	8,541		7,256		25,246		32,502
MISCELLANEOUS							
Water surface	1,669	0.68	1,135	2.96	4,940	3.64	6,075
River channel	1,509	.46	694	1.28	1,932	1.74	2,626
Waste land	691	.33	228	.17	118	.50	346
Town and farm lots	3,330	.50	1,665	1.50	4,995	2.00	6,660
Roads and railroads	2,610	.30	783	.20	522	.50	1,305
Sub-total	9,809		4,505		12,507		17,012
Totals	80,980		52,941		95,074		148,015

* November 1 to March 31.
** Irrigation season, April 1 to October 31.

Estimated Normal Consumptive Use of Water in the East Side Area, Salinas Valley, California

Classification	Area	Winter Consumption*		Summer Consumption**		Annual Consumption	
		Unit	Total	Unit	Total	Unit	Total
	Acres	Feet	Acre-Feet	Feet	Acre-Feet	Feet	Acre-Feet
IRRIGATED CROPS							
Alfalfa	1,978	0.74	1,464	2.40	4,747	3.14	6,211
Lettuce	1,952	.67	1,308	.92	1,796	1.59	3,104
Truck	1,414	.67	947	1.50	2,121	2.17	3,068
Beans (1/2)	3,524	.50	1,762	1.00	3,524	1.50	5,286
Beans (1/2)	3,524	.67	2,361	1.00	3,524	1.67	5,885
Beets	537	.67	360	1.17	628	1.84	988
Guayule	1,599	.83	1,327	.83	1,327	1.66	2,654
Seeds	109	.67	73	1.33	145	2.00	218
Orchard	281	.67	188	1.08	304	1.75	492
Grain	236	.67	158	.72	170	1.39	328
Sub-total	15,154		9,948		18,286		28,234
IRRIGABLE DRY FARM AND GRASS	18,815	0.50	9,407	0.60	11,289	1.10	20,696
NATIVE VEGETATION (Valley Floor)							
Swamp	123	0.91	112	3.60	443	4.51	555
MISCELLANEOUS							
Town and farm lots	970	0.50	485	1.50	1,455	2.00	1,940
Roads and railroads	1,415	.30	425	.20	283	.50	708
Sub-total	2,385		910		1,738		2,648
Totals	36,477		20,377		31,756		52,133

*November 1 to March 31.
**Irrigation Season, April 1 to October 31.

Estimated Normal Consumptive Use of Water in the Forebay Area, Salinas Valley, California

Classification	Area	Winter Consumption*		Summer Consumption**		Annual Consumption	
		Unit	Total	Unit	Total	Unit	Total
	Acres	Feet	Acre-Feet	Feet	Acre-Feet	Feet	Acre-Feet
IRRIGATED CROPS							
Alfalfa	5,208	0.63	3,281	2.57	13,385	3.20	16,666
Lettuce	2,551	.63	1,607	1.00	2,551	1.63	4,158
Truck	5,146	.63	3,242	1.50	7,719	2.13	10,961
Beans	5,247	.63	3,305	1.14	5,982	1.77	9,287
Beets	1,563	.83	1,297	1.17	1,829	2.00	3,126
Guayule	3,102	.63	1,954	1.13	3,505	1.76	5,549
Orchard	710	.63	447	1.34	951	1.97	1,398
Grain	109	.63	69	.71	77	1.34	146
Sub-total	23,636		15,202		35,999		51,201
IRRIGABLE DRY FARM AND GRASS	4,182	0.40	1,673	0.35	1,464	0.75	3,137
NATIVE VEGETATION (Valley Floor)							
Swamp	91	0.91	83	3.74	340	4.65	423
Dense trees-brush-grass	850	.76	646	4.24	3,604	5.00	4,250
Medium brush-trees-grass	2,820	.92	2,594	1.93	5,443	2.85	8,037
Sparse brush-grass	2,610	.63	1,644	1.04	2,714	1.67	4,358
Sub-total	6,371		4,967		12,101		17,068
MISCELLANEOUS							
Water surface	202	0.69	139	3.07	620	3.76	759
River channel	3,335	.46	1,534	1.32	4,402	1.78	5,936
Waste land	326	.25	81	.15	49	.40	130
Town and farm lots	1,060	.50	530	1.50	1,590	2.00	2,120
Roads and railroads	1,261	.25	315	.15	189	.40	504
Sub-total	6,184		2,599		6,850		9,449
Totals	40,373		24,441		56,414		80,855

*November 1 to March 31.
**Irrigation season, April 1 to October 31.

Estimated Normal Consumptive Use of Water in the Arroyo Seco Area, Salinas Valley, California

Classification	Area	Winter Consumption* Unit	Winter Consumption* Total	Summer Consumption** Unit	Summer Consumption** Total	Annual Consumption Unit	Annual Consumption Total
	Acres	Feet	Acre-Feet	Feet	Acre-Feet	Feet	Acre-Feet
IRRIGATED CROPS							
Alfalfa	2,997	0.63	1,888	2.57	7,702	3.20	9,590
Lettuce	353	.63	222	1.00	353	1.63	575
Truck	1,178	.63	742	1.50	1,767	2.13	2,509
Beans (3/4)	6,280	.63	3,956	1.17	7,348	1.80	11,304
Beans (1/4)	2,094	.63	1,319	1.25	2,617	1.88	3,936
Beets	173	.83	144	1.17	202	2.00	346
Guayule	1,057	.63	666	1.13	1,194	1.76	1,860
Orchard	424	.63	267	1.34	568	1.97	835
Grain	45	.63	28	.71	32	1.34	60
Sub-total	14,501		19,232		21,783		31,015
IRRIGABLE DRY FARM AND GRASS	2,289	0.40	916	0.35	801	0.75	1,717
NATIVE VEGETATION (Valley Floor)							
Dense trees-brush-grass	462	0.76	351	4.24	1,959	5.00	2,310
Medium brush-trees-grass	670	.92	616	1.93	1,293	2.85	1,909
Sparse brush-grass	495	.63	312	1.04	515	1.67	827
Sub-total	1,627		1,279		3,767		5,046
MISCELLANEOUS							
River channel	619	0.46	285	1.32	817	1.78	1,102
Waste land	1,886	.25	471	.15	283	.40	754
Town and farm lots	205	.50	103	1.50	307	2.00	410
Roads and railroads	888	.25	222	.15	133	.40	355
Sub-total	3,598		1,081		1,540		2,621
Totals	22,115		12,508		27,891		40,399

*November 1 to March 31.
**Irrigation season, April 1 to October 31.

Estimated Normal Consumptive Use of Water in the Upper Valley Area, Salinas Valley, California

Classification	Area	Winter Consumption*		Summer Consumption**		Annual Consumption	
		Unit	Total	Unit	Total	Unit	Total
	Acres	Feet	Acre-Feet	Feet	Acre-Feet	Feet	Acre-Feet
IRRIGATED CROPS							
Alfalfa	2,018	0.75	1,513	2.66	5,368	3.41	6,881
Truck	1,515	.75	1,136	1.50	2,273	2.25	3,409
Beans (75%)	4,860	.75	3,645	1.25	6,075	2.00	9,720
Beans (25%)	1,620	.75	1,215	1.17	1,895	1.92	3,110
Sugar beets	9,893	.83	8,211	1.17	11,575	2.00	19,786
Guayule	98	.75	73	1.13	111	1.88	184
Seeds	107	.75	80	1.09	117	1.84	197
Orchards	1,322	.75	991	1.34	1,772	2.09	2,763
Grain	509	.75	382	.71	361	1.46	743
Sub-total	21,942		17,246		29,547		46,793
IRRIGABLE DRY FARM AND GRASS	14,155	0.50	7,078	0.33	4,671		11,749
NATIVE VEGETATION (Valley Floor)							
Dense trees-brush-grass	130	0.76	99	4.41	573	5.17	672
Medium brush-trees-grass	8,281	.92	7,618	2.01	16,645	2.93	24,263
Sparse brush-grass	5,346	.63	3,368	1.08	5,774	1.71	9,142
Sub-total	13,757		11,085		22,992		34,077
MISCELLANEOUS							
Water surface	2,440	0.69	1,683	3.19	7,784	3.88	9,467
River channel	2,518	.46	1,158	1.35	3,399	1.81	4,557
Waste land	1,854	.33	612	.12	222	.45	834
Town and farm lots	904	.50	452	1.50	1,356	2.00	1,808
Roads and railroads	1,503	.30	451	.12	180	.42	631
Sub-total	9,219		4,356		12,941		17,297
Totals	59,073		39,765		70,151		109,916

*November 1 to March 31.
**Irrigation season, April 1 to October 31.

Relative Consumptive Use: Normal, 1944 and 1945

In connection with a study of the disposition of water in the Salinas Valley, the State Division of Water Resources requested estimates of consumptive use for the summers of 1944 and 1945 and for the "water years" of 1943-44 and 1944-45. The consumptive use of water for these periods may be estimated after computing the ratio between the consumptive use factor for the given period and the corresponding normal period. For example, the normal consumptive use factor in the Pressure Area is 38.54, while consumptive use factors for summer periods (April 1 to October 31) of 1944 and 1945 are 38.04 and 38.66, respectively, (see Table 17). Then, $\frac{\text{1944 consumptive use factor}}{\text{Normal consumptive use factor}} = \frac{38.04}{38.54} = 0.987$ = Coefficient for reducing normal summer use to 1944 summer use. In a like manner, $\frac{\text{1945 consumptive use factor}}{\text{Normal consumptive use factor}} = \frac{38.66}{38.54} = 1.003$ coefficient for reducing normal summer use to 1945 summer use. Coefficients for reducing normal water year (October 1 to September 30) to 1943-44 and 1944-45 water years were computed in a somewhat similar manner.

These coefficients may also be expressed as percentages of normal, as previously shown in Table 36 of Appendix A, which summarizes the results of the computations.

Computed annual unit consumptive use of water values for the Pressure, East Side, Forebay, Arroyo Seco and Upper Valley areas for normal, 1943-44 and 1944-45 years, are shown in the following tabulation:

Area	Irrigated	Irrigable	Native Vegetation	Miscellaneous	Total
PRESSURE					
Area, acres	50,090	12,540	8,541	9,809	80,980
Consumptive use					
Total normal, acre-feet	84,707	13,794	32,502	17,012	148,015
Normal, unit, feet	1.69	1.10	3.81	1.73	1.83
Water year 1943-44, feet	1.67	1.09	3.77	1.71	1.81
Water year 1944-45, feet	1.70	1.11	3.83	1.74	1.84
EAST SIDE					
Area, acres	15,154	18,815	* 123	2,385	36,477
Consumptive use					
Total normal, acre-feet	28,234	20,696	555	2,648	52,133
Normal, unit, feet	1.86	1.10	4.51	1.11	1.43
Water year 1943-44, feet	1.84	1.09	4.46	1.10	1.42
Water year 1944-45, feet	1.87	1.11	4.53	1.11	1.44
*Swamp Only					
FOREBAY					
Area, acres	23,636	4,182	6,371	6,184	40,373
Consumptive use					
Total normal, acre-feet	51,201	3,127	17,068	9,449	80,855
Normal, unit, feet	2.17	0.75	2.68	1.53	2.00
Water year 1943-44, feet	2.13	.74	2.63	1.50	1.97
Water year 1944-45, feet	2.16	.75	2.67	1.52	1.99
ARROYO SECO					
Area, acres	14,601	2,289	1,627	3,598	22,115
Consumptive use					
Total normal, acre-feet	31,015	1,717	5,046	2,621	40,399
Normal, unit, feet	2.12	0.75	3.10	0.73	1.83
Water year 1943-44, feet	2.08	.74	3.05	.72	1.80
Water year 1944-45, feet	2.11	.75	3.09	.73	1.82
UPPER VALLEY					
Area, acres	21,942	14,155	13,757	9,219	59,073
Consumptive use					
Total normal, acre-feet	46,793	11,749	34,077	17,297	109,916
Normal, unit, feet	2.13	0.83	2.48	1.88	1.86
Water year 1943-44, feet	2.08	.81	2.42	1.84	1.82
Water year 1944-45, feet	2.10	.82	2.45	1.86	1.86

PUBLICATIONS

DIVISION OF WATER RESOURCES

PUBLICATIONS OF THE

DIVISION OF WATER RESOURCES

DEPARTMENT OF PUBLIC WORKS

STATE OF CALIFORNIA

When the Department of Public Works was created in July, 1921, the State Water Commission was succeeded by the Division of Water Rights, and the Department of Engineering was succeeded by the Division of Engineering and Irrigation in all duties except those pertaining to State Architect. Both the Division of Water Rights and the Division of Engineering and Irrigation functioned until August, 1929, when they were consolidated to form the Division of Water Resources. The Water Project Authority was created by the Central Valley Project Act of 1933.

STATE WATER COMMISSION

*First Report, State Water Commission, March 24 to November 1, 1912.
*Second Report, State Water Commission, November 1, 1912, to April 1, 1914.
*Biennial Report, State Water Commission, March 1, 1915, to December 1, 1916.
*Biennial Report, State Water Commission, December 1, 1916, to September 1, 1918.
*Biennial Report, State Water Commission, September 1, 1918, to September 1, 1920.

DIVISION OF WATER RIGHTS

*Bulletin No. 1—Hydrographic Investigation of San Joaquin River, 1920-1923.
*Bulletin No. 2—Kings River Investigation, Water Master's Report, 1918-1923.
*Bulletin No. 3—Proceedings First Sacramento-San Joaquin River Problems Conference, 1924.
*Bulletin No. 4—Proceedings Second Sacramento-San Joaquin River Problems Conference, and Water Supervisors' Report, 1924.
*Bulletin No. 5—San Gabriel Investigation—Basic Data, 1923-1926.
Bulletin No. 6—San Gabriel Investigation—Basic Data, 1926-1928.
Bulletin No. 7—San Gabriel Investigation—Analysis and Conclusions, 1929.
*Biennial Report, Division of Water Rights, 1920-1922.
*Biennial Report, Division of Water Rights, 1922-1924.
Biennial Report, Division of Water Rights, 1924-1926.
Biennial Report, Division of Water Rights, 1926-1928.

DEPARTMENT OF ENGINEERING

*Bulletin No. 1—Cooperative Irrigation Investigations in California, 1912-1914.
*Bulletin No. 2—Irrigation Districts in California, 1887-1915.
Bulletin No. 3—Investigations of Economic Duty of Water for Alfalfa in Sacramento Valley, California, 1915
*Bulletin No. 4—Preliminary Report on Conservation and Control of Flood Waters in Coachella Valley, California, 1917.
*Bulletin No. 5—Report on the Utilization of Mojave River for Irrigation in Victor Valley, California, 1918.
*Bulletin No. 6—California Irrigation District Laws, 1919 (now obsolete).
Bulletin No. 7—Use of Water from Kings River, California, 1918.
*Bulletin No. 8—Flood Problems of the Calaveras River, 1919.
Bulletin No. 9—Water Resources of Kern River and Adjacent Streams and Their Utilization, 1920.
*Biennial Report, Department of Engineering, 1907-1908.
*Biennial Report, Department of Engineering, 1908-1910.
*Biennial Report, Department of Engineering, 1910-1912.
*Biennial Report, Department of Engineering, 1912-1914.
*Biennial Report, Department of Engineering, 1914-1916.
*Biennial Report, Department of Engineering, 1916-1918.
*Biennial Report, Department of Engineering, 1918-1920.

DIVISION OF WATER RESOURCES

Including Reports of the Former Division of Engineering and Irrigation

*Bulletin No. 1—California Irrigation District Laws, 1921 (now obsolete).
*Bulletin No. 2—Formation of Irrigation Districts, Issuance of Bonds, etc., 1922.
Bulletin No. 3—Water Resources of Tulare County and Their Utilization, 1922.
Bulletin No. 4—Water Resources of California, 1923.
Bulletin No. 5—Flow in California Streams, 1923.
Bulletin No. 6—Irrigation Requirements of California Lands, 1923.
*Bulletin No. 7—California Irrigation District Laws, 1923 (now obsolete).
*Bulletin No. 8—Cost of Water to Irrigators in California, 1925.
Bulletin No. 9—Supplemental Report on Water Resources of California, 1925.
*Bulletin No. 10—California Irrigation District Laws, 1925 (now obsolete).
Bulletin No. 11—Ground Water Resources of Southern San Joaquin Valley, 1927.
Bulletin No. 12—Summary Report on the Water Resources of California and a Coordinated Plan for Their Development, 1927.

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Bulletin No. 13—The Development of the Upper Sacramento River, containing U. S. R. S. Cooperative Report on Iron Canyon Project, 1927.
Bulletin No. 14—The Control of Floods by Reservoirs, 1928.
*Bulletin No. 18—California Irrigation District Laws, 1927, Revision.
*Bulletin No. 18-A—California Irrigation District Laws, 1929 Revision.
Bulletin No. 18-B—California Irrigation District Laws, 1931 Revision.
Bulletin No. 18-C—California Irrigation District Laws, 1933 Revision.
Bulletin No. 18-D—California Irrigation District Laws, 1935 Revision.
Bulletin No. 18-E—California Irrigation District Laws, 1937 Revision.
*Bulletin No. 18-F—California Irrigation District Laws, 1939 Revision.
Bulletin No. 18-G—California Irrigation District Laws, 1941 Revision.
*Bulletin No. 18-H—Water Code, Divisions 10 and 11, Irrigation District Laws 1943.
Bulletin No. 19—Santa Ana Investigation, Flood Control and Conservation (with packet of maps), 1928.
Bulletin No. 20—Kennett Reservoir Development, an Analysis of Methods and Extent of Financing by Electric Power Revenue, 1929.
Bulletin No. 21—Irrigation Districts in California, 1929.
Bulletin No. 21-A—Report on Irrigation Districts in California for the year 1929.
Bulletin No. 21-B—Report on Irrigation Districts in California for the year 1930.
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*Bulletin No. 21-D—Report on Irrigation Districts in California for the year 1932.
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Bulletin No. 21-I—Report on Irrigation Districts in California for the year 1937.
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Bulletin No. 21-K—Report on Irrigation Districts in California for the year 1939.
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Bulletin No. 21-M—Report on Irrigation Districts in California for the year 1941.
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Bulletin No. 21-O—Report on Irrigation Districts in California for the year 1943.
Bulletin No. 22—Report on Salt Water Barrier (two volumes), 1929.
Bulletin No. 23—Report on Sacramento-San Joaquin Water Supervisor, 1924-1928.
Bulletin No. 24—A Proposed Major Development on American River, 1929.
Bulletin No. 25—Report to Legislature of 1931 on State Water Plan, 1930.
Bulletin No. 26—Sacramento River Basin, 1931.
Bulletin No. 27—Variation and Control of Salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay, 1931.
Bulletin No. 28—Economic Aspects of a Salt Water Barrier Below Confluence of Sacramento and San Joaquin Rivers, 1931.
Bulletin No. 28-A—Industrial Survey of Upper San Francisco Bay Area, 1930.
Bulletin No. 29—San Joaquin River Basin, 1931.
Bulletin No. 31—Santa Ana River Basin, 1930.
Bulletin No. 32—South Coastal Basin, a Cooperative Symposium, 1930.
Bulletin No. 33—Rainfall Penetration and Consumptive Use of Water in Santa Ana River Valley and Coastal Plain, 1930.
Bulletin No. 34—Permissible Annual Charges for Irrigation Water in Upper San Joaquin Valley, 1930.
Bulletin No. 35—Permissible Economic Rate of Irrigation Development in California, 1930.
Bulletin No. 36—Cost of Irrigation Water in California, 1930.
Bulletin No. 37—Financial and General Data Pertaining to Irrigation, Reclamation and Other Public Districts in California, 1930.
Bulletin No. 38—Report of Kings River Water Master for the Period 1918-1930.
Bulletin No. 39—South Coastal Basin Investigation, Records of Ground Water Levels at Wells, 1932.
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*Bulletin No. 39-J—Records of Ground Water Levels at Wells for the year 1941; including San Jacinto and Antelope Valleys from beginning of record. Precipitation records for the Season 1940-41.
Bulletin No. 39-K—Records of Ground Water Levels at Wells for the Year 1942. Precipitation Records for the Season 1941-42.
Bulletin No. 39-L—Records of Ground Water Levels at Wells for the Year 1943. Precipitation Records for the Season 1942-43.

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Bulletin No. 40—South Coastal Basin Investigation, Quality of Irrigation Waters, 1933.
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Bulletin No. 46—Ventura County Investigation, 1933.
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Bulletin No. 47—Mojave River Investigation, 1934. (Mimeographed.)
*Bulletin No. 48—San Diego County Investigation, 1935. (Mimeographed.)
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Bulletin No. 49—Kaweah River—Flows, Diversions and Service Areas, 1940.
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Bulletin No. 51—Irrigation Requirements of California Crops, 1945.
Bulletin No. 52— Salinas Basin Investigation.
Bulletin No. 52-A—Salinas Basin Investigation—Basic Data.
Bulletin No. 52-B—Salinas Basin Investigation—Summary Report.
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PAMPHLETS

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Water Code, 1943.
Water Rights, Divisions 1, 2 and 4 of Water Code, 1943.
Supervision of Dams, Division 3 of Water Code, 1943.
State Water Plan, Authorities and Boards, Division 6 of Water Code, 1943.
California Administrative Code, Title 23, Waters.
Rules and Regulations Pertaining to Supervision of Dams in California, 1946.
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*Report of the Conservation Commission of California, 1912.
*Irrigation Resources of California and Their Utilization (Bull. 254, Office of Exp. U. S. D. A.), 1913.
*Report, State Water Problems Conference, November 25, 1916.
*Report on Pit River Basin, April, 1915.
*Report on Lower Pit River Project, July, 1915.
*Report on Iron Canyon Project, California, 1914.
*Report on Iron Canyon Project, California, May, 1920.
*Sacramento Flood Control Project (Revised Plans), 1925.
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*Report of California Water Resources Commission to the Governor of California on State Water Plan, 1932.
*Booklet of Information on California and the State Water Plan Prepared for United States House of Representatives' Subcommittee on Appropriations, 1931.
*Bulletin on Great Central Valley Project of State Water Plan of California Prepared for United States Senate Committee on Irrigation and Reclamation, 1932.

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Bulletin No. 1—Publicly Operated Electric Utilities in Northern California, 1941.
*Report on Kennett Power System of Central Valley Project, 1935.
*Report on the Programming of Additional Electric Power Facilities to Provide for Absorption of Output of Shasta Power Plant in Northern California Market, 1938.
The Story of the Central Valley Project of California, 1940.
*Electric Power Features of the State Water Plan in the Great Central Valley Basin of California, 1941.
Auxiliary Electric Power Facilities Required for Central Valley Project, 1942.

* Reports and Bulletins out of print. These may be borrowed by your local library from the California State Library at Sacramento, California.

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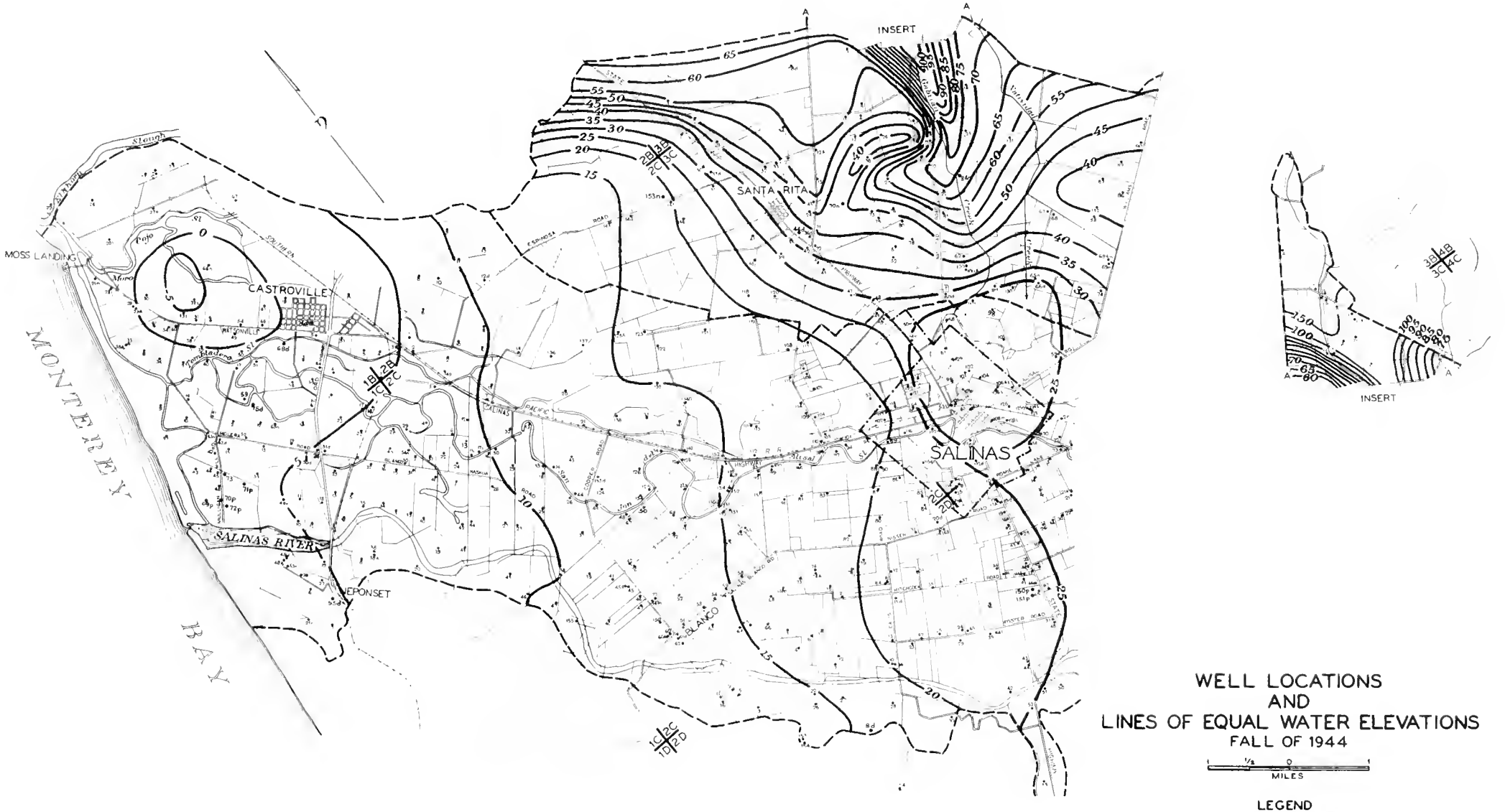

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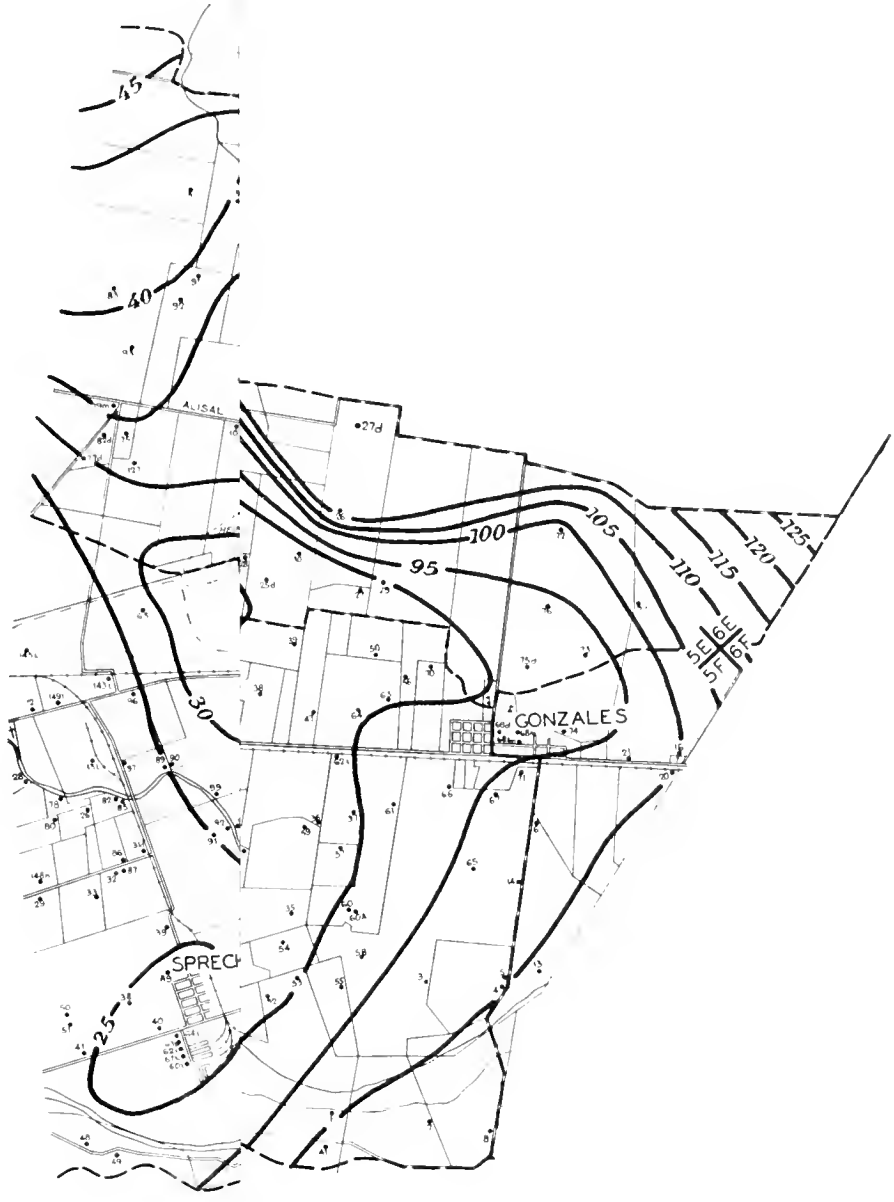

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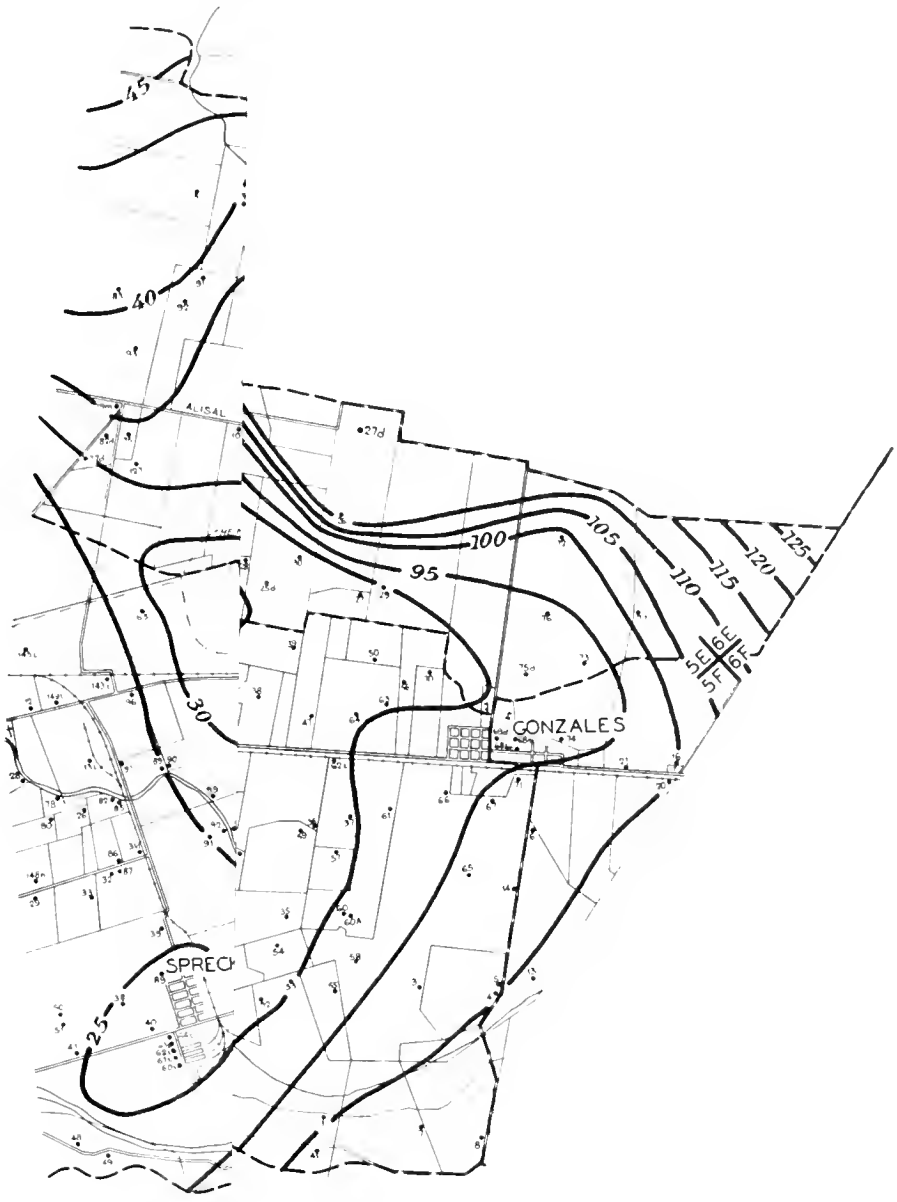

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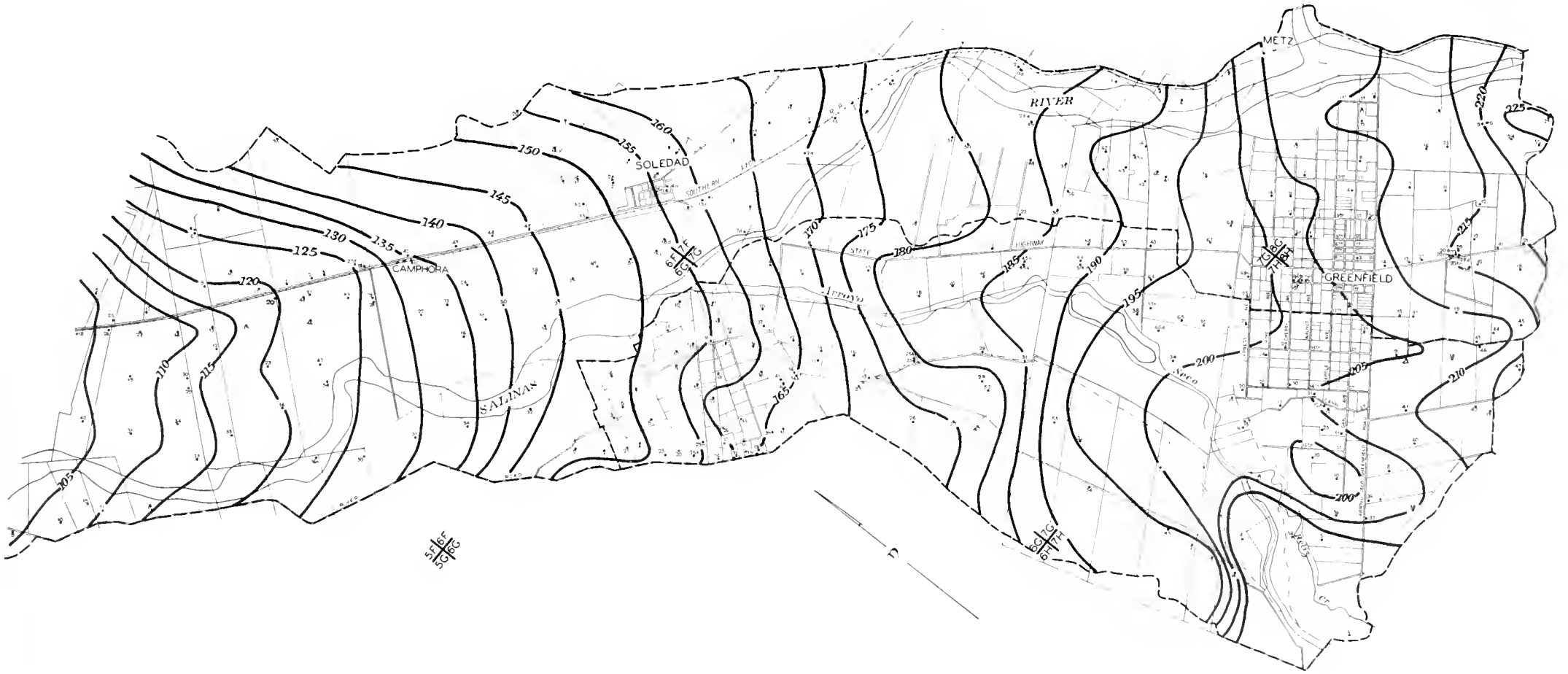

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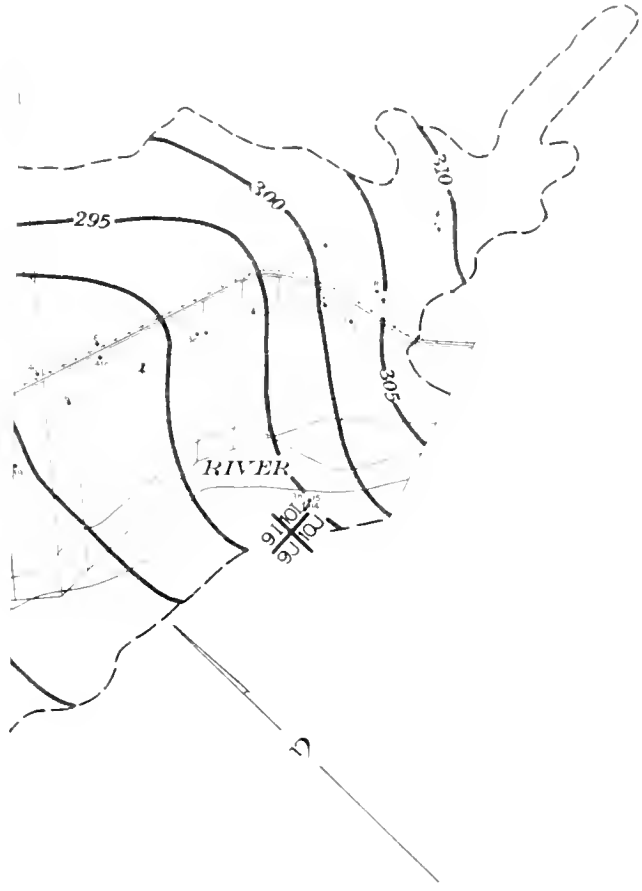

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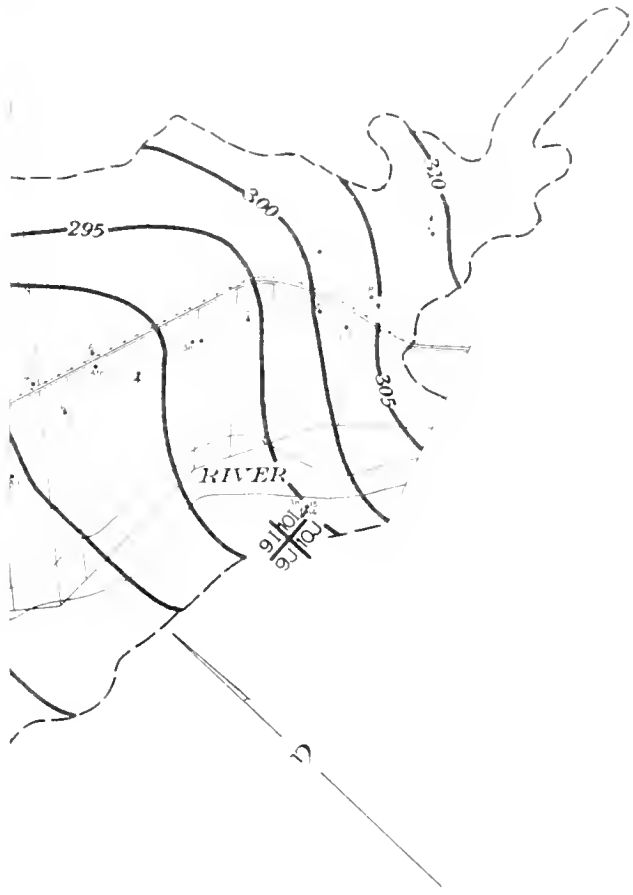

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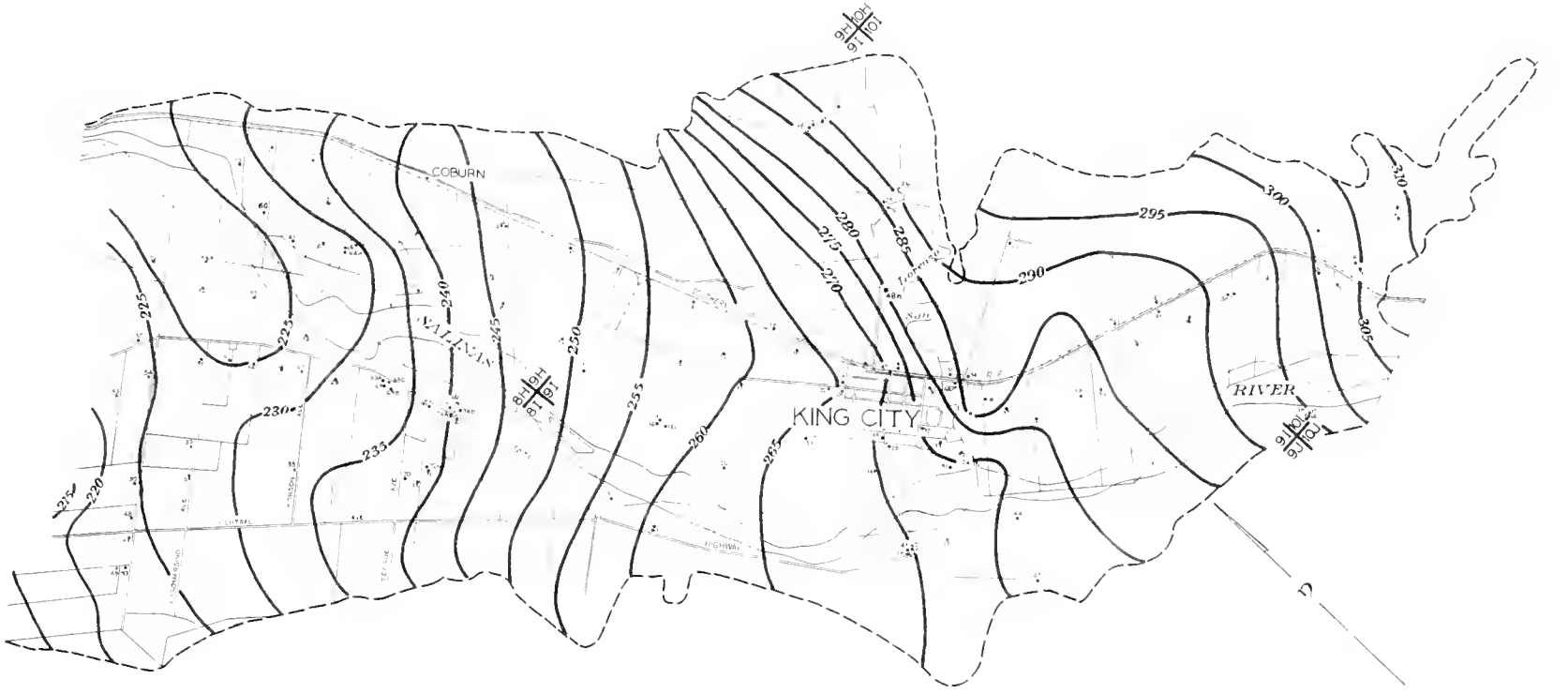

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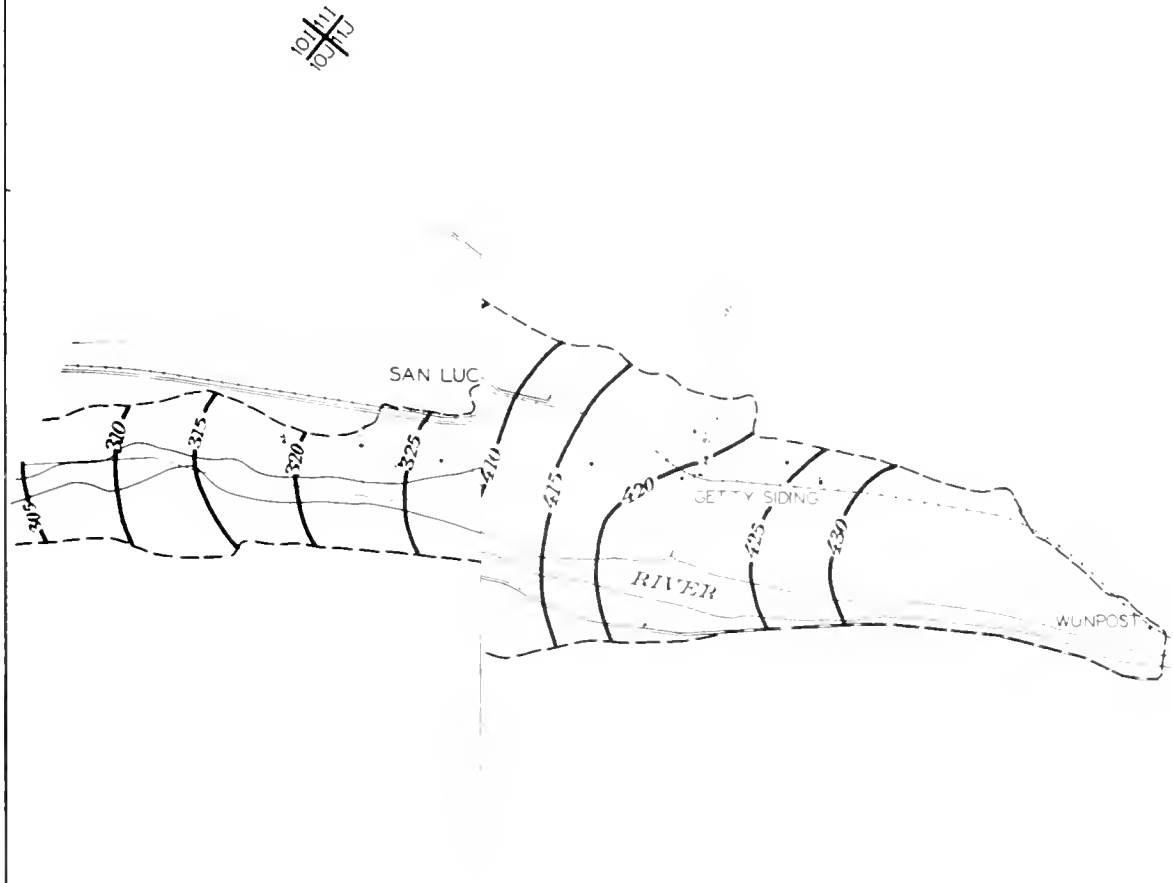

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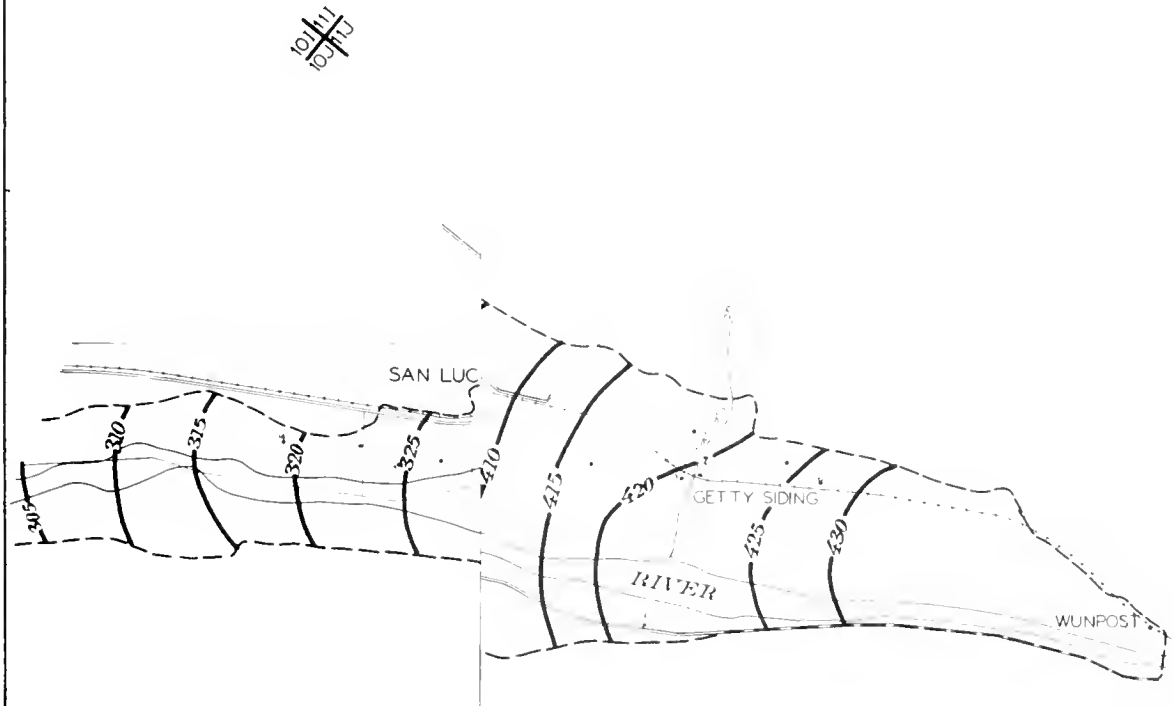

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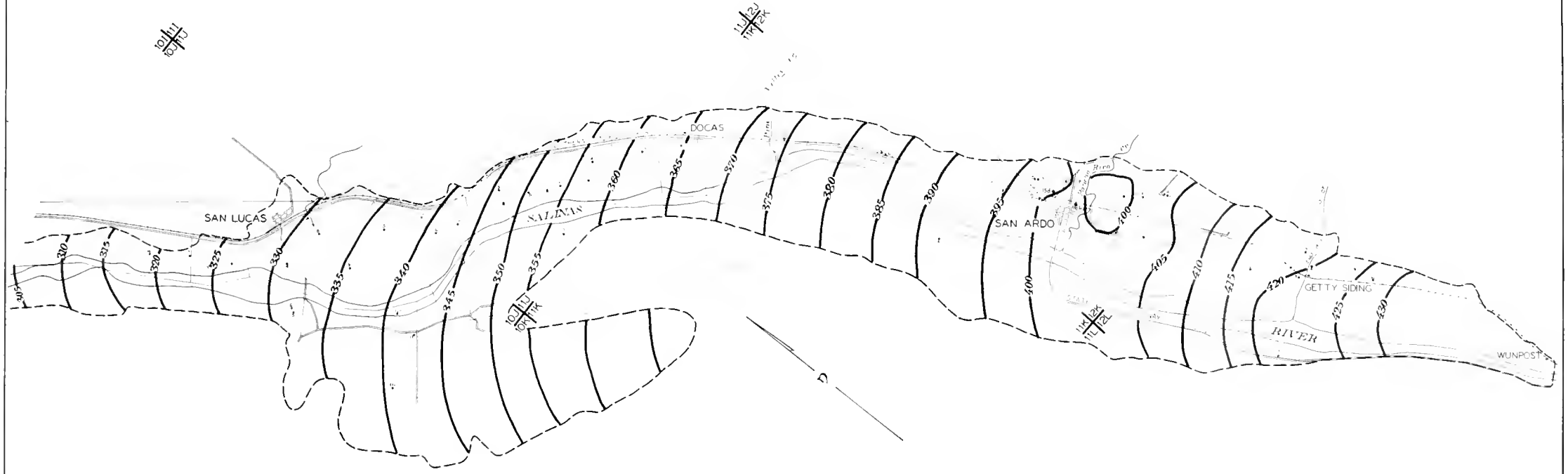

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